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## Virginia Institute of Marine Science 1988-90 Biennial Report

Virginia Institute of Marine Science

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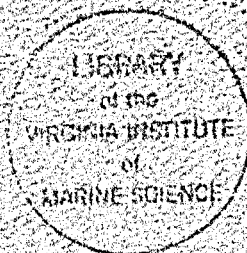
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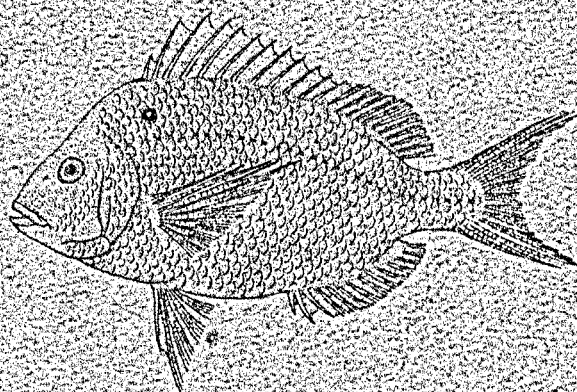
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*The College Of*

**WILLIAM & MARY**

*Virginia Institute of Marine Science  
School of Marine Science*



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1988-90

*1988-90 Biennial Report*





*The College Of*  
**WILLIAM & MARY**

*Virginia Institute of Marine Science  
School of Marine Science*

## *1988-90 Biennial Report*

*for the period  
July 1, 1988 through June 30, 1990*



*The College of William and Mary in Virginia  
is an affirmative action/equal opportunity university.*

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## A Letter from



*Frank O. Perkins*

The 1988-1990 biennium brings to a close a very busy decade for the Institute and School while marking the beginning of a decade that promises to be even more exciting for environmental science. It also marks an important milestone for VIMS/SMS with the celebration of its fiftieth anniversary during calendar year 1990.

Interest in the environment, particularly the Chesapeake Bay and the nation's coastal waters, grew significantly during the 1980's. With this rising tide of interest came increasing population growth and development pressures in coastal areas. Impacts on fragile coastal ecosystems became more noticeable and the need for action by the stewards and resource managers became more urgent. As a result, environmental research organizations like VIMS/SMS faced mounting demands to supply useful and significant information to guide decision makers. As the decade of the 1990's begins to unfold, many challenges and opportunities lie ahead. In 1930 our founding father, William and Mary Biology Professor Donald W. Davis, published an article in *Science* entitled "How The College Can Aid The Oyster Industries." His article provided the basis for a lobbying effort that lasted for ten years and resulted in the establishment of our predecessor the Virginia Fisheries Laboratory (VFL) in 1940.

Dr. Davis noted in his article that college-based scientists have a vital role to play in our society in support of the proper use and conservation of natural resources. He stated that, "The work of the biologist in the oyster industry is not to render judgement unnecessary but to provide a significant basis of information on which more reliable judgement may be based."

Our three-part mission of research, education and public service is well grounded in Dr. Davis' philosophical foundation. Fulfilling our mission is not always simple, but it continues to be challenging and intellectually stimulating.

During 1988-1990 a number of achievements and efforts stand out, far more than space allows me to describe in detail. Let me review several that hold special significance.

Concern over the vitality of the native oyster population of the Chesapeake Bay continues to rise. During the biennium progress was made in our efforts to improve techniques for the culture of oysters. As a result, we are nearing the point where we will be able to transfer hatchery and grow out techniques for the production of oysters for the half shell trade from the research to the commercial phase of operation.

Our ability to predict water movement and the associated transport of dissolved and suspended materials in estuaries and the coastal ocean took a major step forward with development of a three-dimensional, hydrodynamic model of the lower James River. This research tool, which our research team continues to refine, allows us to test various physical situations with regard to the transport of everything from oyster larvae to hazardous chemicals. Work has begun to expand this effort to the York River and the lower Chesapeake Bay.

A collaborative, bay-wide investigation of blue crab population dynamics was initiated in 1989. This study is a joint effort by VIMS/SMS and the University of Maryland's Chesapeake Biological Laboratory. It is the first of its kind and is attempting to quantify abundance, distribution and mortality of the blue crab throughout the Chesapeake Bay.

Completion of the field phase of a flounder stock abundance and migration project showed that approximately two-thirds of the flounder that spend the

## Dean/Director Frank O. Perkins

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summer in Virginia waters migrate south to winter off the North Carolina coast. The remaining one-third of Virginia summer flounder migrate north to Delaware, New Jersey and beyond. This study also showed that the annual fishing mortality for summer flounder was greater than 70% following three poor recruitment years. These findings prompted regulatory action in Virginia and reviews of resource management plans by regional fisheries regulatory bodies.

A year-long series of continuous wave measurements in 1989-1990 demonstrated the need for more precise observational data on waves. This study showed wave patterns to be much more complex than previously thought. It has given rise to an ongoing effort to monitor wave action for use in modeling efforts and to provide real time data for use related to storm events and for predicting plume-event trajectories.

Discovery of a population of minnows with an elevated prevalence of liver neoplasia, in proximity to a highly contaminated site, has provided a potential cause and effect link between environmental contaminants and chronic toxic effects. This organism may serve as an aquatic equivalent of the "laboratory rat" due to its abundance, limited migratory pattern and ease of maintenance in aquaria and cell culture. Immunological, biochemical and pathological experiments using these minnows were initiated during the biennium.

In graduate education, the program underwent a thorough review during the biennium. This periodic effort has resulted in modifications to the program and course offerings.

A study of the VIMS/SMS organizational structure was initiated during the second year of the biennium. This study resulted in the development of a proposal for a new organizational model directed at more clearly defined roles for faculty in responding to our three part mission.

Through formal and informal channels, VIMS serves as a vital resource in the decision making processes related to natural resource management by advising our leaders and fellow citizens on the scientific aspects of practical issues. In this role faculty and professional staff have the opportunity to significantly contribute to natural resources policy making in the Commonwealth and nation; a role not often filled by academic scientists. Demand for reliable scientific information and advice by government, industry and the general public continues to rise.

The strong continuing support from the Commonwealth provides a firm financial foundation for VIMS. With that foundation, our faculty is increasingly successful in seeking grant and contract funding which in 1989-1990 passed the \$5 million mark for expenditures. Additionally, we have significantly benefited from a strong level of support from private individuals and organizations.

Protecting and improving the quality of our environment is one of the most important issues facing our nation and the world. The demand for scientific knowledge is increasing as our society grapples with difficult decisions about the conservation and use of our natural resources. The need for scientists and natural resource professionals with scientific training is growing and will continue to do so. There has not been a better time to be part of an institution that is dedicated to serving society through advancing the frontiers of science and sharing that knowledge with students, decision makers and the general public. The future is indeed a bright one for the Institute and School.



*Donald W. Davis*

# THE COLLEGE OF WILLIAM AND MARY BOARD OF VISITORS 1988 - 1990

Hays T. Watkins . . . . .Rector  
Henry T. Tucker, Jr. (1988-1989) . . . . .Vice Rector  
Stewart H. Gamage (1989-1990)  
James E. Ukrop . . . . .Secretary

Garner N. Anthony	Gilbert M. Grosvenor
The Honorable Sandra D. Bowen (1989-1990)	Pamela C. Harriman
James W. Brinkley	Audrey M. Harris
Edward J. Campbell	Janet Hill (1990)
Sharon A. Coles-Stewart	The Honorable A. Linwood Holton (1988)
The Honorable Richard J. Davis	Carlisle H. Humelsine
Stewart H. Gamage	Joseph R. Koons
Lewis L. Glucksman	Wallace H. Terry
J. Edward Grimsley (1990)	James W. McGlothlin

John H. Tucker, Jr.

## OFFICERS OF ADMINISTRATION 1988 - 1990

Paul R. Verkuil . . . . . President  
Melvyn D. Schiavelli . . . . . Provost  
William F. Merck, II . . . . . Vice President for Administration and Finance  
Edward T. Allenby . . . . . Vice President for University Advancement

## VIRGINIA INSTITUTE OF MARINE SCIENCE SCHOOL OF MARINE SCIENCE ADMINISTRATION 1988 - 1990

Frank O. Perkins . . . . .Director and Dean  
Maurice P. Lynch (1988-1989) . . . . . Associate Dean  
Henry Aceto, Jr. (1989-1990) . . . . . Acting Dean of Graduate Studies  
Robert J. Byrne . . . . . Associate Director for Research  
Paul V. Koehly . . . . . Associate Director for Finance and Administration  
Maurice P. Lynch (1989-1990) . . . . . Assistant Director for Special Programs  
Michael Castagna . . . . . Assistant Director and Scientist-in-Charge of  
Eastern Shore Laboratory  
Robert J. Huggett . . . . . Assistant Director for Division of Chemistry and Toxicology  
Robert J. Orth . . . . . Assistant Director for Division of Biological and Fisheries Sciences  
L. Donelson Wright . . . . . Assistant Director for Division of Geological and  
Benthic Oceanography  
Bruce J. Neilson . . . . . Assistant Director for Division of Physical Oceanography and  
Environmental Engineering



## MARINE SCIENCE DEVELOPMENT COUNCIL

1988-1990

The Marine Science Development Council is an advisory body composed of leaders from Virginia's business and industrial communities who are interested in the continuing vitality of VIMS and its role in advising managers of Virginia's marine and estuarine natural resources. The primary function of the Council is to advise the Dean/Director of the Institute on planning and implementation of research and advisory services programs as they relate to the private sector.

Additionally, the Council advises the Institute on its private sector initiative program. This program is directed toward assisting VIMS in securing private resources to accomplish its goals.

The membership of the Marine Science Development Council for the years 1988-1990 included the following persons:

Mr. George W. Roper, II, Council Chairman  
Marine Safety Consultants/  
Tidewater School of Navigation  
Norfolk, Virginia

Dr. Wallace W. Atwood, Jr.  
Former Director  
Office of International Relations  
National Academy of Sciences  
White Stone, Virginia

Mr. John A. Ahladas  
Senior Vice President  
Virginia Power  
Richmond, Virginia (1990)

Mr. C. C. Ballard  
Ballard Fish & Oyster Company, Inc.  
Norfolk, Virginia

Mr. C. A. Cutchins, III  
Sovran Bank, N.A.  
Norfolk, Virginia

Mr. Louis N. Dibrell, Jr.  
Former Executive Vice President  
Dibrell Brothers, Incorporated  
Danville, Virginia

Mr. Frederick V. Ernst  
Group Vice President - Kraft Products  
Chesapeake Corporation  
West Point, Virginia

Mr. Peter Glasel  
Chairman and CEO  
Weidmuller Group  
West Germany

Mr. Bruce C. Gottwald  
President  
Ethyl Corporation  
Richmond, Virginia

Mr. Emory A. Gross  
President  
Fire Suppression Systems  
Virginia Beach, Virginia

Mr. Brenton S. Halsey  
Chairman and CEO  
James River Corporation  
Richmond, Virginia

Vice Admiral Vincent A. Lascara, U.S.N. (Ret.)  
Vice President  
The Jonathan Corporation  
Norfolk, Virginia

Mr. Robert P. Leber, Director of Facilities  
Newport News Shipbuilding  
Newport News, Virginia

Mr. E. Morgan Massey, President  
A. T. Massey Coal Company, Inc.  
Richmond, Virginia

Mr. John R. Miles, President  
J. H. Miles & Company, Inc.  
Norfolk, Virginia

Mr. William C. Monroe, A.I.A.  
Caro, Monroe, Liang- Architects  
Newport News, Virginia

Mr. Joseph R. Neikirk  
Executive Vice President  
Administration  
Norfolk Southern Corporation  
Norfolk, Virginia

Mr. J. I. Oatts  
Executive Vice President  
Virginia Power  
Richmond, Virginia (1988-1990)

Mr. Charles G. Thalhimer  
Richmond, Virginia

Mr. Guilford D. Ware  
Crenshaw, Ware & Johnson  
Norfolk, Virginia

Captain J. Maury Werth, U.S.N. (Ret.)  
Former Superintendent of the  
U.S. Naval Observatory  
Hagerstown, Maryland

Dr. James A. Wesson, President  
Working Watermen's Association  
Gloucester, Virginia

Mr. Scott C. Whitney, Professor of Law  
George Mason University and  
Director, Institute of Law and Public  
Health Protection  
Arlington, Virginia

Mr. Douglass K. Woolfolk  
The Woolfolk Companies  
Richmond, Virginia

Mr. George A. Zahn, Jr.  
Consulting Engineer  
Gloucester, Virginia

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## GRADUATE EDUCATION

A total of forty-two graduate degrees were awarded to students of the School of Marine Science in the 1988-89 and 1989-90 academic years. The 1988-89 graduate degree awards were conferred on 14 Master of Arts and 6 Doctor of Philosophy students; the 1989-90 awards represented 13 master's degrees and 9 doctorates. A more complete statistical profile is provided on page 7, followed by a listing of students who graduated and their thesis/dissertation titles.

In 1989 an outstanding faculty award for excellence in advisory service was awarded for the first time. In joining two other standing faculty awards (i.e. Outstanding Researcher and Outstanding Teacher Awards), this new award becomes one of three outstanding faculty awards, each of which will be separately awarded on a three-year rotation cycle. The recipient of the 1989 School of Marine Science, Virginia Institute of Marine Science, Outstanding Advisory Service Award was presented to Thomas A. Barnard, Jr., Assistant Professor of Marine Science and Head of the Wetlands Advisory Program of the Division of Biological and Fisheries Sciences. Mr. Barnard has played a leading role in the development and implementation

of the Commonwealth's regulatory program for tidal wetlands contributing directly to the development and formulation of the Commonwealth's Wetlands Act.

The 1989 John M. Zeigler Outstanding Student Achievement Award was received by doctoral candidate David B. Eggleston for his academic and scientific achievements in marine ecology. Eggleston, a student in marine fisheries science whose research focuses on the spiny lobster, has carried out field projects in the Bahamas and Mexico while maintaining a 4.0 grade average.

Nominees for the 1990 Outstanding Faculty Award (i.e. Outstanding Researcher Award) and the 1990 John M. Zeigler Outstanding Student Achievement Award are currently being solicited by the VIMS/SMS Awards Committee and, therefore, selection of awardees will not be completed in time for publication in this report.

The C.E. Richards Memorial Award, which has been established by the Atlantic Coast Conservation Association of Virginia to periodically recognize the VIMS/SMS staff member or student significantly contributing to the needs of recreational fishermen, was presented for the first time in



*Professor Gene Burreson (r) works with graduate student Stephanie Dawson.*

March 1990. The recipient of the award was Jon Lucy.

The School continues to successfully recruit high quality students from all regions of the country and abroad. To assist in this effort, three-year graduate fellowships consisting of a full graduate assistantship stipend plus the waiver of tuition are now offered each year to six newly matriculating students who by virtue of their past academic record and achievements are considered exceptional applicants.

The excellence of the School's graduate students continues to be recognized through the honors and awards they receive from sources outside the Institute. The 1989-90 recipients are listed below.

The maintenance of a high quality graduate education program presumes the periodic review and evaluation of the program's provisions and

policies. In 1989-90, at the request of the Curriculum Committee, all subfaculties conducted a critical review of their respective curricula and a special subcommittee reviewed the core course curriculum resulting in the addition of several new courses and the consolidation or deletion of others, the revision of syllabi for certain core courses, and a revision of the SMS statistics curriculum. Faculty and administration of VIMS/SMS have also recently completed an intensive restructuring study culminating in the development of a model document which proposes a revision of the organizational structure of the Institute. The primary objective of this effort is to clarify the roles individual faculty members play in ensuring the Institute's effective conduct of each of its three important missions (i.e., marine science research, graduate education, and advisory services).

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## Honors and Awards

**Shirley Baker**, International Women's Fishing Association Award

**R. A. Blaylock**, Outstanding student paper in Ichthyology, Annual Meeting, Association of Southeastern Biologists, Charlotte, NC

**Deborah Bodolus**, J. Frances Allen Scholarship

**Nancy Chartier**, Scholarship Award, Student Paper Presentation at 40th Tuna Conference, Lake Arrowhead, CA

**Peter Eldridge**, Student Poster Award, Annual Meeting, American Society of Limnology and Oceanography

**Kathy Kavanagh**, Grant, Lerner-Gray Fund for Marine Research, American Museum of Natural History

**Laurence Libelo**, Seaspaces Scholarship, Houston Underwater Club

**Jiangang Luo**, Lerner-Gray Fund Advisory Committee Award, American Museum of Natural History

**Eugene Olmi**, Best Poster Award, Joint AERS/SEERS meeting, Beaufort, NC; Honorable Mention, Best Student Presentation, Estuarine Research Federation Conference

**Anne Schmitzer**, Award, Presentation of Master's Research at the 7th International Pectinid Workshop, Portland, ME

**Joao Paes Vieira**, Stoye Award (Best Student Paper), American Society of Ichthyologists and Herpetologists

**Beth McGovern**, Best Student Paper, National Shellfisheries Association Meeting



# GRADUATE STUDENT STATISTICAL PROFILE FOR THE 1988 THROUGH 1989 AND 1990 THROUGH 1991 ACADEMIC YEARS

Application, Enrollment and Student Profile Statistics for Incoming Class:

	<u>Applied</u>	<u>Accepted</u>	<u>Enrolled</u>	<u>Mean GPA of Enrollees</u>	<u>Mean GRE of Enrollees Verbal Score (Percentile)</u>	<u>Quantitative Score (Percentile)</u>
1988-1989	72	57	24	3.02	551 (71%)	598 (60%)
1989-1990	94	56	22	3.07	511 (60%)	591 (58%)
1990-1991	102	60	26	3.33	545 (69%)	668 (75%)

Total Enrollment Statistics:

	<u>Enrolled Students</u>			<u>Students on Leave</u>			<u>Enrolled Students' Resident Status</u>		
	<u>Men</u>	<u>Women</u>	<u>Total</u>	<u>Men</u>	<u>Women</u>	<u>Total</u>	<u>In-State</u>	<u>Out-of-State</u>	<u>Foreign</u>
1988-1989	66	38	104	12	12	24	35	49	20
1989-1990	74	33	107	10	12	22	34	48	25
1990-1991	75	35	110	6	5	11	30	57	23

Graduation Statistics:

	<u>Masters</u>	<u>Doctorate</u>	<u>Total</u>
1988-1989 (Includes Aug/Dec 1988 and May 1989 Graduates)	14	6	20
1989-1990 (Includes Aug/Dec 1989 and May 1990 Graduates)	13	9	22
1990-1991 (Includes Aug/Dec 1990 and projected May 1991 Graduates)	15	15	30

# GRADUATE STUDENT DEGREES AWARDED

## Doctor of Philosophy Degrees, with Titles of Dissertations and Major Professor(s)

- Booth, Paul M., Jr.** 1989. Nitrogen and Phosphorus Cycling Strategies in Two Tidal Freshwater Macrophytes, *Peltandra virginica* and *Spartina cynosuroides*. (Carl H. Hershner)
- Byles, Richard A.** 1988. Behavior and Ecology of Sea Turtles from Chesapeake Bay, Virginia. (John A. Musick)
- List, Jeffrey H.** 1988. Long Wave Generation by Wave Groups in the Nearshore. (L. Donelson Wright)
- Rice, Charles D.** 1989. The Influence of Tributyltin on Various Aspects of Activation and Reactive Oxygen Formation in Oyster Toadfish (*Opsanus tau*) Macrophages. (Beverly A. Weeks)
- Szedlmayer, Stephen T.** 1988. Early Life History of Weakfish *Cynoscion regalis* (Bloch and Schneider). (John A. Musick and Michael P. Weinstein)
- Thoney, Dennis A.** 1989. Comparative Ecology of the Parasites of the Spot, *Leiostomus xanthurus* Lacepede, and the Atlantic Croaker, *Micropogonias undulatus* Linnaeus (Sciaenidae) in the Cape Hatteras Region. (William J. Hargis, Jr.)
- Bochenek, Eleanor A.** 1989. Virginia's Pelagic Recreational Fishery: Biological, Socio-economic and Fishery Components. (William D. DuPaul and Jon A. Lucy)
- Catallo, William James, III.** 1989. Effects of Selected Nitrogen-Containing Aromatic Compounds (NCACs) on Physiological Properties in *Escherichia coli*. (Michael E. Bender)
- Edstrom, Robert D.** 1989. PCB Congener Analysis with Hall Electrolytic Conductivity Detection. (Robert J. Huggett and William G. MacIntyre)
- Eldridge, Peter M.** 1989. The Effect of Nitrogen and Phosphorus Supply Ratios and Dilution Rate on Phosphorus Uptake and Mineralization in Continuous Flow Microcosms. (Kenneth L. Webb)
- Gallo, Lino J.** 1990. Atmospheric Input of Polycyclic Aromatic Hydrocarbons to the Sea Surface Microlayer. (Robert J. Huggett)
- Kim, Sung Chan.** 1990. Inner Continental Shelf Benthic Boundary Layer Dynamics and Suspended Sediment Transport. (L. Donelson Wright)
- Koepfler, Eric Thor.** 1989. Heterotrophic Bacterial Production: Relationships to Biological and Abiological Factors in Estuarine Environments. (Howard I. Kator and Richard L. Wetzel)
- Monteiro-Neto, Cassiano.** 1990. Comparative Community Structure of Surf-Zone Fishes in the Chesapeake Bight and Southern Brazil. (John A. Musick)
- Williams, Ruth L.** 1989. Uptake Kinetics and Toxicity of Diazinon in the American Oyster, *Crassostrea virginica* (Gmelin). (Morris H. Roberts, Jr.)
- Master of Arts Degrees in Marine Science with Titles of Theses and Major Professor(s)*
- Baker, Beverly E.** 1989. Effect of Water Column pH and  $\text{NO}_3$  on Ortho-Phosphate Release Rates from Freshwater Sediments. (Bruce J. Neilson)
- Bellmund, Sarah Anne.** 1988. Assessing Environmental Stress on the Loggerhead Sea Turtle (*Caretta caretta*) in Virginia Waters. (John A. Musick)
- Chartier, Nancy J.** 1988. The Effects of At-Sea Killing and Storage Methods on the Quality of Recreationally-Caught Northern Bluefin Tuna, *Thunnus thynnus*. (William D. DuPaul and Jon A. Lucy)
- Desfosse, Joseph C.** 1989. Meristic and Morphometric Comparison of Three Juvenile *Alosa* Species; Blueback Herring, *A. aestivalis*; Alewife, *A. pseudoharengus*; and American Shad, *A. sapidissima*. (Joseph G. Loesch)
- Eggleston, David B.** 1988. Predator-Prey Dynamics Between the Blue Crab *Callinectes sapidus* Rathbun, and Juvenile Oysters *Crassostrea virginica* (Gmelin). (Roger L. Mann)
- Espourteille, Francois A.** 1988. An Assessment of Tributyltin Contamination in Sediments and Shellfish in the Chesapeake Bay. (Robert J. Huggett)
- Furman, Carol.** 1989. Mitochondrial DNA Variation in Striped Bass, *Morone saxatilis*, from the Rappahannock River, Virginia. (Herbert M. Austin)
- Hepworth, Daniel A.** 1988. Response of a Partially Mixed Coastal Plain Estuary to Storm Events. (Albert Y. Kuo)
- Klinger, RuthEllen C.** 1988. Age and Growth of Juvenile Loggerheads, *Caretta caretta*, from Chesapeake Bay. (John A. Musick)

- Ledwin, Jane M.** 1988. Sedimentation and its Role in the Nutrient Dynamics of a Tidal Freshwater Marsh. (Carl H. Hershner and Robert J. Byrne)
- McCarthy, Kevin J.** 1989. The Influence of Salinity on the Swimming Behavior of Larval *Crassostrea virginica* (Gmelin). (Roger L. Mann)
- Mason, Pamela Anne.** 1989. The Standing Stock of Organic Matter in a Man-Made Brackish Marsh and its Resource Management Implications. (Thomas A. Barnard, Jr. and Carl H. Hershner)
- Snyder, Ellen Pafford.** 1988. Distribution and Taxonomy of Endolithic Algae Occurring in the Shells of *Crassostrea virginica* Throughout the Lower James River, Virginia. (Roger L. Mann and Dexter S. Haven)
- Wohlgemuth, MaryAnn.** 1988. Estimation of Net Aerial Primary Production of *Peltandra virginica* (L.) Kunth Using Harvest and Tagging Techniques. (Carl H. Hershner)
- Burger, Ned.** 1989. Hypoxic Water Transport by Sub-tidal Circulation from Chesapeake Bay to the Lower Rappahannock Estuary. (Albert Y. Kuo)
- Chen, Jia.** 1989. Effect of Nitrogen and Phosphorus Enrichment on Lipid and Fatty Acid Composition of Estuarine Microplankton. (Fu-Lin E. Chu and Kenneth L. Webb)
- Hoffman, Frederick A.** 1989. Carbon, Nitrogen, and Phosphorus Discharge from the Altamaha River, Georgia. (Richard L. Wetzel and Charles S. Hopkinson)
- Howard-Strobel, Mary M.** 1989. Bottom Sediment Mobility at the Wolf Trap Site in the Lower Chesapeake Bay. (L. Donelson Wright)
- Jin, San A.** 1990. Numerical Model Study of Estuarine Residual Circulation and Stratification Variations During Spring-Neap Tidal Cycles. (John M. Hamrick)
- McGovern, Elizabeth Robinson.** 1990. Characterization of *Minchinia* sp. Spores (Ascomycota: Haplosporidiidae) Infecting *Teredo navalis* L. and *Teredo furcifera* Von Martens (Mollusca: Teredinidae) in the Western North Atlantic. (Eugene M. Bureson)
- Ozalpaskan, Hakan.** 1989. Distribution Analysis of Heavy Minerals on the Inner Continental Shelf of Virginia. (Carl H. Hobbs, III)
- Peery, Christopher A.** 1989. Cannibalism Experiments with the Blue Crab (*Callinectes sapidus* Rathbun): Potential Effects of Size and Abundance. (Robert J. Orth and Jacques van Montfrans)
- Reay, William Glendon.** 1989. Sub-surface Hydrodynamics and Nutrient Exchange within an Extensive Tidal Freshwater Wetland. (Carl H. Hershner)
- Roegner, G. Curtis.** 1989. Recruitment and Growth of Juvenile *Crassostrea virginica* (Gmelin) in Relation to Tidal Zonation. (Roger L. Mann)
- Schmitzer, Anne Catherine.** 1990. The Gametogenic Cycle of *Placopecten magellanicus* (Gmelin) in the Mid-Atlantic Bight. (William D. DuPaul)
- Wilcox, Julia K.** 1989. Recent Vegetation and Area Changes in a Tidal Marsh Located at Pope's Creek, Virginia. (Gene M. Silberhorn)
- Wyanski, David M.** 1990. Patterns of Habitat Utilization in O-age Summer Flounder (*Paralichthys dentatus*). (Brenda L. Norcross)



Masters degree recipient Beverly Baker.



## SUMMER INTERN PROGRAM

The summer intern/research aide program provides the opportunity for undergraduates who might be considering research careers to obtain some first hand experience in marine science. This program also allows the School of Marine Science to target groups that are underrepresented in the field of marine science and provide an exposure to a field not available on their own campuses. The gains of this program to VIMS/SMS include assistance to Institute scientists in their research programs and a larger, more focused pool of graduate program applicants.

Undergraduate participants in the program working with an assigned mentor select a topic to pursue during the summer. At the end of the 10-week internship, the students present their research results to the faculty and staff of VIMS/SMS during a formal seminar. In addition, some of the interns have been able, through a program supported by the National Science Foundation and the American Society of Limnology and Oceanography, to present their work at a national scientific meeting.

These programs are proving their worth in the increasing numbers of applications from groups underrepresented in the marine sciences both from direct participants in the program and from colleges and universities that have had under-

graduate participation in these programs. During the 1989-90 time period, the summer intern program has received support from the Union Camp Corporation and the National Science Foundation Research Experience for Undergraduates Program.



1989 Summer Interns.

### Summer Interns 1989

**Teresa Bryan**  
Pembroke State University  
VIMS/Union Camp  
**Angela Bryant**  
Elizabeth City State University  
NSF  
**Tom Byrom**  
Hampton University  
NSF  
**Fonya Crockett**  
Jackson State University  
NSF  
**Dionne Hoskins**  
Savannah State College  
NSF  
**Ajua Henderson**  
South Carolina State College  
NSF  
**Stacy Nelson**  
Jackson State University  
NSF

**William O'Connell**  
University of Virginia  
VIMS/Union Camp  
**Gene Speight**  
NC Central University  
NSF  
**James Stewart**  
Hampton University  
NSF  
**Lisa Yarborough**  
NC Central University

### Summer Interns 1990

**Margaret Calvert**  
Lynchburg College  
VIMS/Union Camp  
**April Evans**  
Lynchburg College  
NSF  
**Doug Gantt**  
Hampton University  
NSF

**David Hamm**  
Hampton University  
NSF  
**Dionne Hoskins**  
Savannah State College  
NSF  
**Robert McGee**  
Jackson State University  
NSF  
**Mia Morris**  
Jackson State University  
NSF  
**Caroline O'Farrell**  
Oral Roberts University  
VIMS/Union Camp  
**Kimberly Reubush**  
Mary Baldwin College  
VIMS/Union Camp  
**Angela Smith**  
Norfolk State University  
NSF

## COMPUTER CENTER

In the fiscal year just ended, the PRIME computer experienced usage in excess of the previous year. This is presented in the following table:

	1988-1989	1989-1990
Charges:	\$438,414	\$609,637
CPU hours	980	1,654
Connect hours	56,056	54,668
Disk hours	576	849

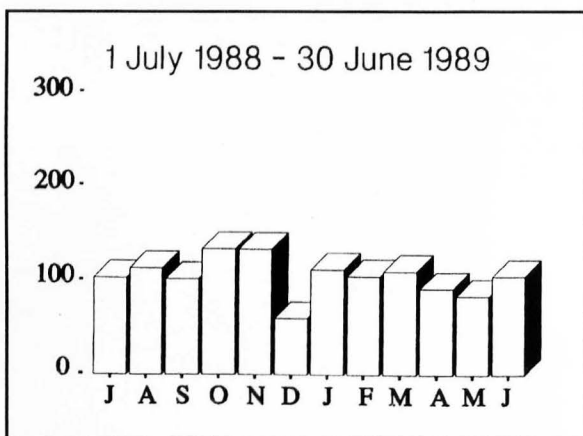


Figure 1. Monthly use in FY 1988-1989.

Comparison of the charges for the two years is difficult since the charging rate was increased in FY89-90. However, the hours of use can be compared. It is seen that the CPU hours increased by 69% over FY88-89. This is an indication of increased activity in processor use ("computational activity"). "Connect hours" is a measure of "real time" spent at terminals logged in to the computer. This dropped slightly last year, and is probably an indication of the impact of PC's assuming some of the load. Typical PC use (e.g. word processing) is highly interactive, but has a relatively low computational effort. The significant increase in disk hours shows an increase in activity in accessing files which is due to the increased CPU activity as well as to the addition of more disk drives at the beginning of the year. The dollar charges are based on a "machine unit hour (MUH)" which is a combination of CPU, disk and connect times.

The PRIME computer continues to provide significant computational and data management service. At the same time progress toward a *symbiosis* of PC's and large computers via networking has been made.

Figures 1 and 2 present the CPU use each month for FY88-89 and FY89-90 respectively. The axes are to the same scale so comparison between the years is easy to make.

### Networking progress

The Institute is now a node on the Virginia Education and Research Network, VerNET. VerNET is part of the nationwide Internet system which also has links to many foreign countries. Due to budgetary limitations, the only computer connected to the network is the PRIME. However, all PRIME users now have access to other computers nationwide and worldwide. This access allows transfer of files of information between computers, and, if the authority has been granted, use of the computational capabilities of remote computers. Thus, our scientists are now able to directly access super-computers if their work requires it. In addition, all PRIME users can now send and receive electronic mail worldwide. This is a powerful research tool since it enables scientists to exchange thoughts and ideas rapidly although they may be separated by continents and oceans.

The Computer Services department is developing relatively inexpensive methods for connecting other local area networks at the Institute to the central node and to each other. This forms an interim solution to our goal to provide high speed computer connectivity throughout the Institute.

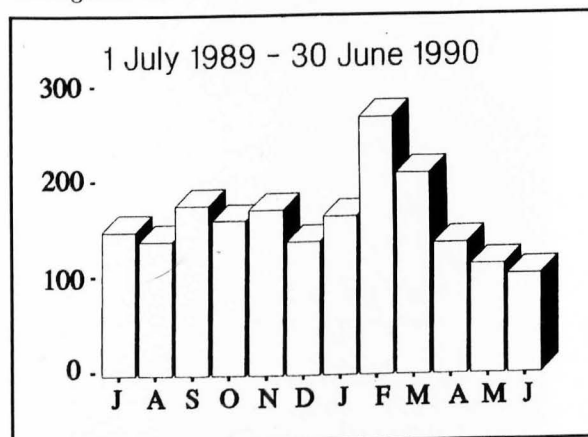


Figure 2. Monthly use in FY 1989-1990.

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## LIBRARY

**T**he 1988-1990 biennium brought significant changes to the VIMS Library. Ms. Susan Bar-  
rick, Library Director since 1969, retired in February 1990. Among Susan's many lasting contributions to the library are her leadership which enabled the library to begin automating its operations and the vision, dedication and hard work which created the Chesapeake Bay Bibliography as a printed index and developed it into its present format as a microcomputer database. Susan's cheerfulness, optimism and enthusiasm, her commitment to meeting the needs of VIMS library users, and her deep and abiding concern for the welfare of both VIMS and the Chesapeake Bay will be remembered fondly by all those who knew her.

Two grants enabled the VIMS Library to enhance its technological capabilities. Using General Assembly funds granted to the William and Mary Libraries for strengthening access to information, the library purchased a microcomputer to enable library users to conduct their own literature searches in two locally available databases, the Chesapeake Bay Bibliography and the Aquatic Sciences and Fisheries Abstracts. The library was also fortunate to be among the twenty-one academic libraries in Virginia awarded a telefacsimile machine by the State Council of Higher Education. By providing rapid transmission of materials requested on interlibrary loan, these fax machines constitute a network which facilitates the sharing of resources among members of the Virginia academic library community.

Among the special projects conducted by the VIMS Library during 1988-1990 were: extensive on-line literature searching for the Chesapeake Research Consortium to support the authors of papers in its publication, "Perspectives on the Chesapeake Bay, 1990: Advances in Estuarine Science;" the continued development of the Chesapeake Bay Bibliography database, which ceased in February 1990 when funding for this project ended; and the beginning of a cooperative project with Dr. George Grant at VIMS to create a microcomputer database of Chaetognath literature.

Gifts to the library during the biennium included Dr. George Grant's personal library of publications



*VIMS library.*

on Chaetognaths, a sizeable gift of books and library furniture from Deep Sea Ventures of Gloucester Point, an extensive collection of literature on oysters and clams from retired VIMS professor Dexter Haven, and publications on fish parasites and diseases from Dr. William Hargis. The library's budget was again supplemented by much-needed private funds.

Services to VIMS library patrons during the biennium included obtaining 1,726 publications on interlibrary loan, conducting 160 database searches in various DIALOG databases, and the continuation of free searches in the Chemical Abstracts database. The library provided interlibrary loans of 491 books and journal articles from our collection to other libraries.

### **Library Holdings at the End of FY 1989-1990:**

Periodical subscriptions	500
Periodical titles (current and non-current)	800
Monographic titles	18,498
Bound volumes (books and periodicals)	42,428
Maps and charts	3,483

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## VESSELS SERVICE CENTER

**T**he Vessels Service Center is engaged in an ongoing, development program to support the Institute in a wide variety of marine research. As technological advances continue on the marine science scene, the challenge presented to accommodate these advances by improving the research vessel fleet remains a demanding responsibility for those who strive to furnish the vessel support required to achieve the Institute's objectives. Use of onboard computers has increased sharply during recent years. This trend has occurred throughout the fleet of trailerable boats on an almost equal basis with the largest vessels. Equipped with appropriate shelter from the elements and adequate power sources, small outboard motor boats are performing precise scientific surveys at cost-saving advantages. It is not unusual for the Institute's 65-foot **R/V BAY EAGLE** to return from an offshore survey involving several state-of-the-art systems, then transfer this equipment directly onto a

trailerable boat which deploys the same systems near the headwaters of the estuary on the following day.

During the past year, the Institute's trawl survey for juvenile fish and crabs has been revamped to incorporate several new innovations in data collection and processing methods. The survey began more than 30 years ago, with the early sampling performed aboard the 60-foot **R/V PATHFINDER**. By 1980, the survey had been shifted onto the 42-foot **R/V CAPTAIN JOHN SMITH**, following modifications which enabled this vessel to dedicate its use specifically to trawling. As refinements became available in the electronic processing of a catch, the opportunity was realized to further reduce the trawl vessel size. During 1990, the 29-foot **R/V FISH HAWK**, was designed, constructed, equipped, calibrated and commissioned to perform the trawl survey. This new vessel is operating at less than half of what its predecessor cost on a daily basis. The **R/V FISH HAWK** has literally been designed around the electronic processing capabilities made available by state-of-the-art technology. The construction of this vessel is revolutionary in many ways. The use of marine aluminum alloys throughout assures years of low maintenance expense. The propulsion is provided by a modern, high speed diesel engine coupled to a variable speed marine transmission. Hydraulic powered winches and net handling equipment make strenuous work much safer and easier for the crew. In addition to the scientific computers and printers, this vessel offers the navigational benefits of radar, loran and a color fathometer as well as the comforts of a heated cabin and a microwave oven. The vessel was designed for an anticipated service life of 25 years. The Institute's return on the **R/V FISH HAWK** investment should be outstanding.

Most recently, improved technology has enabled the Vessels Service Center to upgrade its ability to conduct shore based operations. Scheduling software has been implemented by the vessel office. In addition to knowing detailed logistic requirements for every field project that has resulted in a vessel being scheduled, valuable summary information relative to previous patterns of usage is readily available. The Diving Safety Officer has also implemented a comprehensive diving log to track the activity of Institute Dive Team members through the use of database software and a micro-computer.



# Research

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## DIVISION OF BIOLOGICAL AND FISHERIES SCIENCES



*Researchers prepare to bring a trawl on board the R/V CAPT. JOHN SMITH.*

**T**he Division of Biological and Fisheries Sciences, headed by Dr. Robert J. Orth, is involved in a broad range of biological and ecological topics from population genetics of finfish, estuarine nutrient dynamics and assessing impacts of disease on oyster populations to ecosystem modeling. The division has a strong element in the advisory area, in particular, providing expert advice on wetlands management and the status of finfish and shellfish stocks.

### **Finfish, Vertebrate Ecology and Systematics Program**

This program is comprised of several diverse projects which deal with various aspects of the systematics, ecology, biology and population dynamics of marine vertebrates. Major projects are detailed below.

#### **Chondrichthian Biology**

With support from the federal Wallop-Breaux program, Drs. John A. Musick and Steven Branstetter and Mr. Tom Sminkey continued the long-line program to assess the distribution and abundance of sharks from Chesapeake Bay out to Norfolk Canyon and as far south as Cape Hatteras, NC. Comparison of catch data from current research with the Institute's historical data set (dating back to 1973) has indicated a drastic decline in the abundance of sharks during the last ten years. This decline is probably directly attributable to gross overfishing. Upon being advised that strict regulation of the shark fishery was needed, the Virginia Marine Resources Commission (VMRC) responded by passing new regulations to outlaw long-lining in Virginia and to limit both the recreational and commercial catches.

Other aspects of the project included: Mr. Chris Tabit's studies on the comparative morphology of dermal denticles in deep-sea dogfishes and their relation to drag reduction; Mr. David Hata's study of comparative gill morphology as related to growth and life history strategies; and Ms. Eileen Grogan's work on evolution of the immune system in Chondrichthys.

#### **Fish Systematics Program**

The fish collection, managed by Ms. Carole Baldwin, continued to grow in both size and diversity. Fish specimens from the museum were used in

research projects by VIMS faculty and graduate students and borrowed by institutions as far away as Sidney, Australia. The fish collection also was used as an educational resource in William and Mary graduate and undergraduate courses and in various community programs. Efforts to computerize the museum catalog continued, with help from Ms. Kim Callis. Plans were made for a new scientific storage building that will house the overcrowded fish collection and provide laboratory and storage space for fisheries programs.

#### **Juvenile Finfish Stock Assessment**

VIMS has been monitoring the distribution and abundance of commercially, recreationally and ecologically important finfish species in the Lower Chesapeake Bay and its tributaries for over 35 years. A central focus of this effort, headed by Dr. James Colvocoresses and assisted by Mr. Patrick Geer, Ms. Joy Dameron, Messrs. David King, Deane Estes, Don Seaver, and Paul Gerdes, has been systematic trawl and seine surveys aimed at estimating the relative annual reproductive success, as measured by survey catch rates of juvenile (young-of-the-year) individuals, for these species. The data management unit is headed by Mr. Chris Bonzek, assisted by Mr. Bobby Harris. The resultant "juvenile indices" are a key measure used in the formulation of fishery management plans and the resultant harvest regulations. Recent emphasis placed on the monitoring of Chesapeake Bay living resources by the Chesapeake Bay Agreement provided the impetus during the 1988-90 biennium for highly significant expansions of both of the regular monitoring surveys, a summer beach seine survey which primarily targets juvenile striped bass and a broad-scope monthly trawl survey. This expanded sampling effort is resulting in more accurate and reliable population estimates. It is also providing a more sound basis for habitat use evaluations and investigations into the relationships between annual reproductive success and climatic and water quality conditions.

#### **Finfish Biology, Ecology and Population Dynamic Studies**

Dr. J. Musick and Messrs. Joseph Desfosse and Deane Estes completed the field phase of a flounder stock and migration program after tagging and releasing over 12,000 flounder while Messrs. Donald Seaver, Deane Estes, David Hata, and Ms. Deborah Bodulus continued sampling for summer juvenile flounder on Virginia's Eastern Shore and the lower portion of the York River. The results showed most flounder that spend the summer in Chesapeake Bay



*Jiangang Luo uses an electronic board to measure fish.*

and Virginia inshore waters migrate south along the coast to winter off North Carolina. About one third of the tagged Virginia flounder migrate north of Virginia to Delaware and New Jersey before they return in the summer. Study data also showed that annual fishing mortality for summer flounder was greater than 70% and that flounder had suffered very poor recruitment for three years. The VMRC has responded by closing all Virginia waters to trawling and limiting the recreational bag limit to ten fish per person per day. Data for this project are currently being used by regulatory bodies to revise existing resource management plans for summer flounder.

Dr. Mark E. Chittenden, Jr.'s research has focused on the fish fauna of the mainstem of the Chesapeake Bay in Virginia. Cruises were made aboard R/V JOHN SMITH using trawls to collect fish at 48 stations randomly selected each month of the year from a spatially stratified sampling design superimposed on a sampling frame of nearly 17,000 potential stations. More than 500,000 individuals of 76 species were identified, counted, or measured.

Two very abundant fishes, bay anchovy and spot, dominated the fauna and made up almost 97% of the total catch. These species were ubiquitous throughout the year (bay anchovy) or June-December (spot).

Preliminary analyses suggest time is much more important a factor than area in determining nekton abundance in the mainstem Chesapeake. Spatially, preliminary analyses found total catches consistently higher in the Western Shore Littoral strata than in the Eastern Shore Littoral. Diversity generally increased proceeding downbay, but there was no consistent cross-bay pattern.

Dr. Herb Austin has started monitoring young-of-the-year spot condition indices each month from fish taken by the VIMS river trawl survey. Once a "normal" seasonal condition index is determined, departures due to cold winters, hot summers, disease or parasites, or contaminants can be recognized and tracked through time.

Cassiano Monterio-Neto completed his Ph.D. work on the zoogeography and community structure of surf-zone fishes in the North and South Atlantic Oceans. Mr. Joao Paes Vieira is continuing a similar comparison of estuarine fish communities. These studies provide insights into the environmental and historical factors that affect species diversity and abundance. Another important study, pursued by Mr. Jiangang Luo, was centered on reproduction, age and growth in the bay anchovy. Mr. Luo's data suggest that this species abundance may result from it having the highest rate of egg production known for similar small forage species.

Research on two important recreational and commercial species, bluefish and weakfish, funded by Wallop-Breaux and Atlantic States Marine Fisheries

Commission, has focused on identifying how many different stocks are present in the mid-Atlantic Bight, and on their geographic and seasonal range. Multiple stocks complicate management efforts; consequently, it is important to know how many are in the Bight.

Mr. Daniel Scoles, a Ph.D. student, recently completed a morphometric analysis of weakfish between Long Island and South Carolina. He compared his results to the mtDNA analysis conducted by Dr. John Graves, which concluded that only one genetic stock of weakfish exists along the mid-Atlantic coast, Long Island through Hatteras. Scoles' morphometric analysis, on the other hand, suggested that northern and southern weakfish differ in measured variables possibly suggesting two distinct stocks. This difference is the result of a single stock (genetically) that spawns over the full geographic range in different environmental conditions. Environmental differences, for example temperature, during the spawning season or early life stages often result in morphometric differences. Graves and Scoles presented the results of the analysis to an Atlantic States Marine Fisheries Commission Plan Review Committee. Their results will be incorporated in the 1990-1991 revision of the interstate fisheries management plan for weakfish.

During 1987-1990, Dr. Austin conducted a morphometric analysis that separated bluefish spawned in the spring south of Hatteras from those spawned during the summer on the Continental Shelf of the mid-Atlantic Bight. Dr. Graves' mtDNA results however, showed a single genetic stock throughout the mid-Atlantic Bight. This suggests that, like the weakfish, there is a single stock with environmentally induced morphological variance. Austin also found that the percentages of "spring spawned" and "summer spawned" bluefish taken in the Chesapeake Bay over the 1987-1990 period have changed. In the Bay there has been a shift from predominantly "spring" to "summer" fish. This change is apparently the result of differences in recruitment success during the two periods due to fluctuations in the winds and temperature during, or just after, spawning.

Ms. Deborah A. Bodolus is examining the transport of spot larvae from offshore spawning areas and the subsequent recruitment of post-larvae/juveniles into the Chesapeake Bay. Ms. Bodolus is examining current patterns, and the resultant transport of spot larvae, with the aid of a computer simulation of mid-Atlantic Bight circulation developed by personnel at National Oceanic and Atmospheric Administration (NOAA). Results from the model will be used to identify potential transport pathways and causative mechanisms. The relative importance of each climatic factor (wind, river flow, and tidal) will be assessed with regard to the transport of spot to the Chesapeake Bay. Results from the circulation model will allow development



of a statistical recruitment model to evaluate the year-class strength of spot. This information can then be used by state and federal agencies for the management of spot within the Chesapeake Bay.

#### **Anadromous Fish**

Dr. Joseph G. Loesch heads the Anadromous Fish Program which includes an array of research projects. National Marine Fisheries Service (NMFS) has funded two ongoing monitoring studies in Virginia's rivers and estuarine waters of Chesapeake Bay: one to assess the biological and fishery statistics of alosid fishes (American shad, alewife, and blueback herring), and another similar study of striped bass stocks. These data are essential to support fishery management decisions. Ms. Loisirene Blumberg and Mr. Bruce Hill are responsible for the data management in the alosid and striped bass projects, respectively. NMFS has funded an ongoing mark-recapture study of striped bass in the James River, and the Virginia Marine Resources Commission and the U.S. Fish and Wildlife Service have funded an ongoing mark-recapture study of striped bass in the Rappahannock River. The objectives of the mark-recapture studies are to evaluate the exploitation of striped bass both within and outside the river system of capture, study migratory patterns, and assess the fidelity of coastal migrants to the river of release in subsequent spawning seasons. This study will benefit Virginia and those Atlantic coastal states that share the objective of the responsible management of striped bass. Mr. Philip Sadler functions as field chief in both projects and is the primary "reader" of striped bass scales to determine age structure. Similarly, Ms. Blumberg is the primary reader of alosid scales and otoliths for age determinations. Messrs. Curtis Leigh and Henry Wooding prepare scales and otoliths for reading and assist in field work.

Ms. Joice Davis conducts aerial observations and telephone interviews to assess pound nets and gillnet fishing activities as part of a study of commercial fishing effort in Virginia waters. Mr. James Owens is responsible for the placement and recovery of logbooks for recording fishing effort with cooperating fishermen and is the liaison with the fishing industry for this and other projects. The fishing effort data are basic for anadromous and non-anadromous fishery modeling and in management planning.

Graduate students in the anadromous program are also involved in an array of projects. Mr. Douglas Dixon is studying the diel periodicity of alosid juvenile fishes, while functioning as field chief for an ongoing juvenile index project funded by NMFS which assesses alosid year class success. Mr. Steven Gornak is studying the meristic and morphometric characteristics of striped bass as potential stock discriminators. Ms. Steffany Dawson is studying diel

and seasonal variation in pelagic fish communities in estuarine waters. Mr. Brian Shaner is assessing differences in aging methodologies used with American shad. With funding by the U.S. Fish and Wildlife Service, Mr. Edward Sismour is studying the ecology of larval alewife and blueback herring. The phenomenon of compensatory growth in American shad is being investigated by Ms. Roanne Trapani.

#### **Marine Turtles**

The sea turtle project team, Dr. Musick, Mr. John Keinath and Ms. Debra Barnard-Keinath, continued to collect data on sea turtle strandings in Virginia and estimate abundance of sea turtles from aerial surveys. They also continued studies using satellite transmitters to track the fall and winter migration of loggerhead sea turtles. Other studies included Mr. Bill Jones' work on the effect of the microdistribution of nest temperatures on determination of sex ratios in loggerheads at Back Bay Wildlife Refuge. Ms. Mary Rybitski has begun to study PCB concentrations in stranded sea turtles.

#### **Marine Mammals**

As the individuals responsible for National Marine Fisheries Service designated Marine Mammal Stranding Center in Virginia, VIMS scientists, Dr. Musick and Ms. Barnard-Keinath, continued to collect data from stranded whales and dolphins. In addition, populations of bottlenose dolphins were monitored using aerial surveys, and the team



*Joseph Desfosse (l) and John Keinath prepare to release a sea turtle.*

responded to strandings of several sick or injured cetaceans and seals. Mr. Lee Morgan is working with Dr. Musick and Mr. Charles Potter of the Smithsonian Institution to analyze the temporal and geographic frequencies of all recent cetacean strandings from Virginia.

#### **Coelacanth Biology**

Dr. Musick continued his editorial work on the book, *Evolution of Coelacanths and the Biology of Latimeria chalumnae*. This book resulted from the research organized by Dr. Musick at VIMS in January 1989. VIMS coelacanth tissues were sent to scientists all over the U.S. and to Germany, Canada, Japan, and Australia. Dr. Musick is joined in this effort by junior editors, Dr. Michael Bruton (Director, J. L. B. Smith Institute, South Africa) and Dr. Eugene Balon (Professor of Biology, Guelph University, Guelph, Ontario). Technical assistance for this project has been provided by Ms. Carole Baldwin and Ms. Kim Callis.

#### **Larval Fish Nutrition**

Drs. Fu-Lin Chu and K. L. Webb and graduate student Surreya Ozkizilcik are studying the nutritional requirements and development of microencapsulated diets of striped bass and striped bass hybrid larvae. The specific nutritional requirements and feeding physiology of striped bass and hybrid larvae are not known. Development of intensive commercial hybrid striped bass production requires reliable diets that consistently satisfy nutritional requirements of the cultured animals. Currently this team is working to improve the nutritional quality of the live food *Artemia* through enhanced feeding of the live food with long chain omega-3 polyunsaturated fatty acids. Another goal of this research is to determine the correlations between the biochemical composition of the live food and the growth and survival of the larval fish being fed.

#### **Genetics Program**

VIMS initiated a molecular genetics research program in 1990 to investigate the genetic basis of stock structure in natural populations of marine organisms. The program, under the direction of Dr. John Graves, is well equipped to describe population structure by analyzing molecular variation of both proteins and mitochondrial DNA.

The major efforts of the program during 1990 focused on stock structure of bluefish and weakfish, two important commercial and recreational fish species that undergo strong seasonal movements along the mid-Atlantic coast. Although molecular variation was found within each species, the lack of differentiation among fish of different ages or from different locations suggests that a single, mid-Atlantic stock exists for each species.

The genetics program is also analyzing the stock structure of wide ranging pelagic fishes. Dr. Graves

is beginning an analysis of the stock structure of several billfish (marlin, sailfish, spearfish) species, and with Dr. Musick and Mr. Ed Heist, is studying the population structure of several species of sharks which migrate between Virginia and the lower Gulf of Mexico.

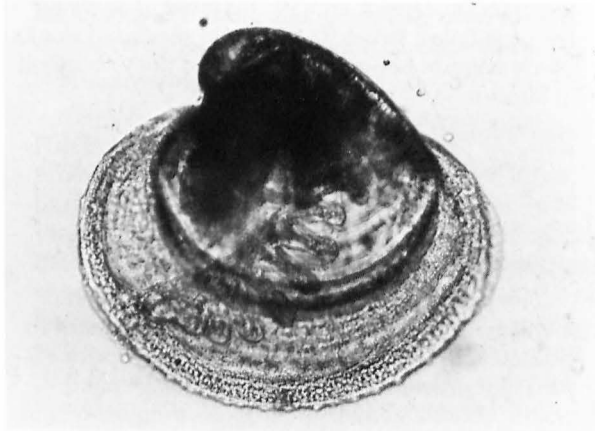
#### **Microbiology**

Studies and advisory activities of the Microbiology Program area covered a variety of research topics under two general headings.

##### **Shellfish Microbiology**

The program mandate to assist the molluscan shellfish industry continued with a commitment to evaluate and develop microbiological indicator systems that provide for protection of the public health, classification of shellfish growing areas, and maintenance of water quality. To achieve these goals VIMS microbiologists Dr. Howard Kator and Ms. Martha Rhodes participated in the technical development of a proposed National Indicator Study designed to establish growing area microbiological standards based on public health risk. Federal funds obtained to support this project are now being used to develop a manual of indicator methods and evaluate a human-specific viral indicator of fecal pollution.

Dr. Kator and Ms. Rhodes focused special emphasis on evaluation of a specific assay method developed for enumeration of another recently proposed viral indicator of fecal pollution, the male-specific coliphage. These bacteriophage viruses, which are parasitic to certain strains of *E. coli* and abundant in sewage, were enumerated in local Virginia shellfish growing waters using a *Salmonella typhimurium* WG49 host that has been genetically altered through addition of a plasmid coding for production of *E. coli* sex pili. Sex pili are structures produced by certain *E. coli* to which male-specific phages must attach to initiate infection. Despite the routine occurrence of elevated levels of the traditional fecal coliform indicator in the typical non-point source impacted waters examined, confirmed male-specific phages were rarely detected in 100 ml water or 10 g sediment samples. These observations suggest the male-specific phage may not be an appropriate indicator for these waters. Of interest was the occurrence of phages lytic to the female "parent" of the assay host (i.e., somatic *Salmonella* phages) that were detected in estuarine feeder streams, the estuary proper and were especially abundant in sediments. These phages were highly specific for certain *Salmonella* serovars and did not infect a variety of coliform and heterotrophic bacterial isolates from the same study area. Additional research is necessary to examine the ecology of these phages and their relationship to *Salmonella* spp. contamination in the estuary. Some of the



*Oyster larvae.*

phage work was part of the Master's thesis of Mr. David Boyd.

Other studies were completed that focused on the occurrence and detection of proposed alternate bacterial indicators of fecal pollution in estuarine waters. Evidence was obtained to support the hypothesis that certain indicators may permit differentiation of human from animal sources of fecal pollution. Although these alternate indicators may not be suited for routine monitoring of growing area water quality, their value as investigatory tools to identify and differentiate sources of fecal pollution to feeder streams and estuarine areas should be explored. Dr. Kator continued his participation as technical expert to the international Interstate Shellfish Sanitation Conference.

#### **Aquatic Microbiology**

As the result of a perceived public health risk, a field study was initiated by Ms. Martha Rhodes to determine the seasonal occurrence of the bacterial pathogen, *Aeromonas hydrophila*, and to obtain data on physicochemical factors that affect its densities in a local freshwater lake. Prior to this study the lake, which overflows into a tidal creek of the James River, was used for both recreational and instructional purposes by the College of William and Mary. Field results obtained by microbiologists show the lake is entrophic and contains high densities of this pathogen. Future studies are planned to focus on the relationship between nutrient levels and *A. hydrophila* densities and to identify trophic processes that affect its ecology.

#### **Malacology**

The program in malacology encompasses several component projects focusing predominantly on the oyster resource of Virginia.

#### **Monitoring, Biology and Ecology**

Studies of the early life history of bivalves have focused on the role of larval swimming behavior in retention of larvae in stratified estuaries, the effects of hypoxia and anoxia on larval and post larval physiology, and attempts to quantify growth and mortality during the transition from competent-to-settle larvae through small oysters that are identifiable in traditional benthic surveys. Behavior studies, by Dr. Roger Mann and graduate students Bernadita Campos and Kevin McCarthy, examined four species as role models: surf clams, coot clams, Rangia clams and oysters. Clam larvae exhibit species-specific salinity preferences and these are similar to those of the adults. By contrast, oyster larvae generally exhibited surfaceward swimming but this behavior decreased as surface salinity decreased. The limited swimming capability of bivalve larvae leaves them very much at the mercy of intense hydrographic events. Hypoxia and anoxia studies, effected by Dr. Mann and graduate student Shirley Baker in collaboration with Dr. Roger Newell (University of Maryland) and Dr. John Widdows (Plymouth Marine Laboratory, England), focused on oyster larvae. Tolerance of larvae to anoxia increases with body size. Our data indicate that under severe hypoxic or anoxic stress small larvae maintain activity and can swim sufficiently fast for sufficient duration to swim out of deeper, oxygen depleted water. By contrast, the settling and post settlement stages reduce activity in a conservative, "wait and see" posture. In general, early larvae appear more robust in the face of low oxygen stress than originally suggested; however, the settling and immediate post settlement stages remain vulnerable to hypoxia and anoxia stress. Studies focusing on metamorphosis and post metamorphosis events, by Dr. Mann and graduate students G. Curtis Roegner and Patrick Baker, indicate that larvae prefer to settle subtidally in the salinities of the York River, but final distribution is strongly influenced by post settlement losses to predation. Early attempts to quantify the proportion of apparently competent-to-settle larvae that do indeed settle are encouraging, but much work remains to be completed in this area.

Studies of the commercial oyster resource remain a central part of our research efforts. This effort includes contributions from Dr. Mann, Dr. Bruce Barber, Mr. Reinaldo Morales, Ms. Julia Rainer, Mr. Kenneth Walker, and graduate student Lyn Cox. Oyster broodstock studies in the James River indicated that egg production per oyster was higher at the more saline locations until the impact of endemic diseases became evident and mortalities



were recorded. There is concern that eggs produced at low salinities appeared to have generally low viabilities - in simple terms, egg numbers alone are not enough. A large number of broodstock in a low salinity area may not have the same value to the fishery as a smaller broodstock in higher salinity. Unfortunately, we do not have the latter in the Virginia portion of the Bay due to endemic diseases. Dr. Barber and Mr. Walker continue to provide monitoring of oyster resources in the Virginia portion of the Chesapeake Bay. Oyster spatfall for 1988 and 1989 was lower than the mean for the 1980-89 decade, indicating a continuing decline of the Virginia oyster resource. Further depletion of potential broodstock in the James River by sustained fishing pressure continues. Lower salinities associated with increased rainfall have reduced the presence of the oyster disease MSX, but *Perkinsus marinus* remains in essentially all oyster beds in the Virginia portion of the Bay.

A program has been initiated to examine alternatives to the native oyster for use in restoration of the Virginia oyster industry. In a collaborative effort Dr. Mann, Dr. Barber and the oyster hatchery staff initiated a program in which native oysters, *Crassostrea virginica*, and nonnative Pacific oysters, *C. gigas*, were cultured in the VIMS oyster hatchery as both normal (2 sets of chromosomes per cell, termed diploid) and genetically altered with reduced reproductive capacity (3 sets of chromosomes per cell, termed triploid) specimens. As part of a collaborative effort with Dr. E. Bureson and the Oyster Disease Program, these oysters were being examined for susceptibility to the resident disease organism, *Perkinsus marinus* in laboratory systems. To date, results suggest that *C. gigas* exhibits low susceptibility to *Perkinsus marinus*; however, challenge by MSX disease cannot be effected until permission is obtained to place *C. gigas* (triploid) directly in the waters of the Chesapeake Bay. Such introductions are the source of continuing debate.

#### Defense Capacity and Disease Tolerance in Oysters

Dr. Fu-Lin Chu and graduate student Jerome La Peyre's research focuses on the study of defense capacity and disease resistance in native (the eastern oyster, *Crassostrea virginica*) and non-native (the Pacific oyster, *C. gigas*) oysters. Their major effort uses different cell stages of the disease organism, *Perkinsus marinus*, to identify mechanisms contributing to the resistance to pathogenic infections and to elucidate the effects of environmental impacts on oyster defense mechanisms. To identify resistant traits, defense-related activities of individual oysters are measured and related to disease incidence. Chesapeake Bay's oyster supply has been depleted by diseases, in particular by the disease organism *Perkinsus* in recent years. To revive the oyster fishery in Virginia, it is necessary to identify oysters or

oyster strains which better cope with diseases. Preliminary work has demonstrated that challenging Pacific oysters with *Perkinsus* significantly increases the defense-related cellular and humoral activities in this non-indigenous species of oysters. It was also found that the defense-related humoral activities were inversely related to the prevalence of *Perkinsus* infection in three populations of native oysters.

Recently, grants have been awarded to Dr. Chu by the National Marine Fisheries Service and Jeffress Memorial Trust of Virginia to continue research efforts on the defense capacity and disease resistance in oysters. In collaboration with Drs. Mann, Bureson and Barber and Mr. Castagna, Dr. Chu will also compare the defense capacity and *Perkinsus* susceptibility of native and non-native oysters including diploid and triploid strains under different environmental conditions.

Studies of *Perkinsus* dose response in oysters is another area of study. The biological process for transmitting disease in oysters is not clear. A preliminary study has indicated that when oysters were exposed in water of  $23.0 \pm 1.6^{\circ}\text{C}$  and salinity of 18.6 ppt, *Perkinsus* incidence in oysters was a function of dosages of *Perkinsus* infective particles administered to the oysters, whereas in water of similar salinity at temperature  $26.0 \pm 1.6^{\circ}\text{C}$ , *Perkinsus* incidence in oysters was not related to the concentrations of *Perkinsus* infective particles injected into the oysters.

In the summer of 1989 Drs. Chu and Bureson initiated a project with a visiting scientist, Dr. Natarajan from India, to investigate which *Perkinsus* cell type in its life cycle is the most effective and the primary agent for disease transmission among oysters. Preliminary results showed that *Perkinsus* biflagellated zoospores appeared to be most effective in inducing *Perkinsus* infection in oysters. Oysters inoculated with zoospores developed *Perkinsus* infections in 8 days while it required 14 and 37 days for oysters inoculated with trophozoites and prezoosporangia, respectively, to acquire *Perkinsus* infections.

#### Oyster Diseases

Dr. Eugene M. Bureson, several graduate students, and colleagues have been studying ways to reduce the effects of two protozoan diseases on Chesapeake Bay oyster populations. The two parasites, *Perkinsus marinus* (dermo disease) and *Haplosporidium nelsoni* (MSX disease), have had a severe impact on the oyster industry in Virginia. Investigations have concentrated on enhancing the natural resistance of the native oyster, *Crassostrea virginica*, and on determining the susceptibility to the diseases of a non-native oyster, *Crassostrea gigas*.

A selective breeding program has been initiated with various oyster strains that are either survivors from disease endemic areas in the lower

Chesapeake Bay or have been selected for resistance to *H. nelsoni* over six generations in Delaware Bay. A three-year disease exposure study conducted in the lower Chesapeake Bay by Dr. Bureson, Ms. Juanita Walker and Ms. Judy Meyers indicates that progeny from three different *H. nelsoni*-selected strains are not susceptible to *H. nelsoni*, but that they are very susceptible to *P. marinus*, and mortality has been high. This result suggests that resistance is not a generalized response, but is specific for each parasite. Progeny of survivors from endemic areas for both diseases had overall lower mortality than the *H. nelsoni* selected strains. In an attempt to enhance disease resistance, strains with the lowest mortality are being hybridized and also bred as pure lines by oyster hatchery manager Ken Kurkowski.

Experiments by graduate student Judy Meyers in which *C. gigas* held in quarantine were challenged with *P. marinus* resulted in low intensity infections in most of the oysters, but infections never developed further and no disease-induced mortality was observed. Most *C. virginica* in the same system developed high intensity infections and mortality was high. These results suggest that *C. gigas* is much less susceptible to *P. marinus* than *C. virginica* and may be useful in attempts to rejuvenate the Chesapeake Bay oyster industry.

#### Crustacean Ecology

The Crustacean Ecology program is conducting a diverse array of field and laboratory studies including a comprehensive series of investigations of blue crab ecology and fisheries biology encompassing all life-history stages in Chesapeake Bay; a predator-prey field study with the queen conch in the Bahamas; and an extensive field investigation on spiny lobster recruitment dynamics and the efficacy of artificial shelters in enhancing spiny lobster and finfish populations in the Caribbean.

NOAA-Sea Grant and the Commonwealth of Virginia have funded an ongoing study by Mr. Jacques

van Montfrans, Drs. Romuald Lipcius and Robert Orth, and graduate student Geno Olmi, the first recipient of the Willard A. Van Engel Fellowship, on the recruitment dynamics and settlement processes of blue crab postlarvae and early-stage juveniles. These investigations have documented lunar, semi-lunar and tidal patterns in planktonic availability and settlement of blue crab postlarvae, which invade estuarine settlement habitats such as eelgrass beds, on nocturnal flood tides in late summer and fall. Graduate students Bruce Layman and Karen Metcalf have found that the likelihood of settlement

is affected by developmental state of the postlarvae and specific habitat features. The results from this intensive program are being applied in population models that might provide accurate and precise estimates of population fluctuations in future year classes. In addition, the aforementioned principal investigators have successfully launched a Sea Grant-funded national research effort of blue crab recruitment comprising investigators from several states along the Atlantic and Gulf coasts of the U.S. The initial data set derived from this collaborative effort suggests widespread coherence in certain patterns of postlarval recruitment, thereby providing the requisite background information for future research efforts.

Dr. Romuald Lipcius is conducting an NSF-funded study on predator-prey dynamics between blue

crabs, their benthic prey and habitat features in collaboration with Drs. Anson Hines (Smithsonian Institution) and Tom and Donna Wolcott (North Carolina State University). In particular, sediment features, cannibalism in the blue crab, and benthic prey availability of species such as soft-shelled clams regulate population dynamics of the blue crab and its prey. Complementary studies funded by the Commonwealth of Virginia and a private donation by Mr. Lewis L. Glucksman were conducted by graduate student Randa Meehan and showed that the blue crab is an opportunistic omnivore in Chesapeake Bay. It also showed that interference between actively foraging blue crabs reduces their feed-



Sue Mauger samples for blue crab megalopae and juveniles in a seagrass bed.

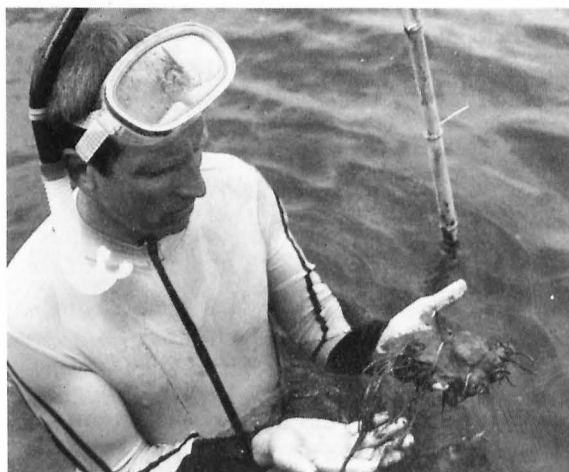
ing efficiency and concurrently enhances the likelihood of survival of their prey. Graduate student Kirt Moody, the most recent recipient of the Willard A. Van Engel Fellowship, has begun an intensive investigation of the mechanisms and consequences of cannibalism in the blue crab.

NOAA, through the Chesapeake Bay Stock Assessment Committee (CBSAC), has funded a collaborative, bay-wide investigation of blue crab population dynamics between Dr. Lipcius and Dr. Brian Rothschild of the University of Maryland's Chesapeake Biological Laboratory. This study is unique in that it is the first of its kind in attempting to quantify bay-wide abundance, distribution and mortality rates of the blue crab in Chesapeake Bay. Dr. Eric Garnick, postdoctoral research associate, graduate student Marcel Montane, and senior technician Paul Gerdes are also funded under the NOAA-CBSAC grant and the Commonwealth of Virginia to analyze the bay-wide data and additional long-term historical data of trawl-survey abundance of the blue crab in Chesapeake Bay tributaries. They will be starting experiments on habitat-specific survival of juvenile blue crabs during the coming year. These results are expected to provide critical information for the formulation of various fishery models for the blue crab.

NSF, NOAA-National Undersea Research Program, and the Caribbean Marine Research Center have funded Dr. Lipcius and graduate students David Eggleston and Livingston Marshall to conduct a series of investigations on Caribbean spiny lobster, queen conch and various species of finfish. These include field experiments to test the feasibility of enhancing spiny lobster and finfish production with artificial shelters; field studies on the recruitment dynamics of spiny lobster postlarvae; and field experiments on factors regulating the survival of queen conch in nursery habitats. Graduate students David Plotner and Jonathan Mintz have begun complementary studies on spiny lobster and finfish ecology. These studies are being conducted in Florida, the Bahamas and Mexico. In addition, NSF has funded a new study by Drs. Lipcius and Graves to examine stock characteristics of the spiny lobster with recent genetics techniques (i.e., mitochondrial DNA analysis).

### **Submerged Aquatic Vegetation**

Mr. Kenneth Moore and Drs. Richard Wetzel and Robert Orth have been involved in research on submerged aquatic vegetation (SAV) focusing on the development of quantitative relationships between Chesapeake Bay submerged grasses and the estuarine environment. Of particular importance to federal and state regulatory agencies, as well as the academic community, have been a series of field, laboratory microcosm, and model simulation studies which have determined the specific level of water



*Robert Orth holds a SAV sample in his hand.*

quality characteristic of areas suitable for SAV growth. SAV requires water that is low in dissolved nutrients and low in turbidity for optimum growth and survival. Studies by Mr. Moore and Ms. Hilary Neckles have documented the sensitivity of SAV to changes in levels of these factors. They have determined that SAV populations can be important bioindicators of the health of the Bay and can be useful in indicating improvements in Bay water quality. These results are being used by the states of Virginia, Maryland and Delaware as well as the federal government in development of surface water quality criteria.

As a complement to the organism and community-level studies described above, Dr. Orth, Ms. Judy Nowak and Mr. Moore have been investigating the Bay-wide population-level response of SAV to changing environmental conditions. Remote sensing studies combined with geographic information system (GIS) analyses are being used to monitor and document changes in SAV throughout the entire Bay region including Maryland waters. Trends in eutrophication and SAV response are also being tracked on a macro-scale in this system level approach.

Finally, Mr. Moore and Dr. Orth continued projects on SAV phenology, seed germination and transplantation techniques. These studies have two objectives: (1) to develop a thorough understanding of the reproductive process of SAV in the stressed Chesapeake Bay environment; and (2) to develop techniques that can be used to assist the revegetation process either in site specific situations, where compensation is required by regulatory agencies, or in areas where improvements in water quality have been achieved.



### Nutrient Cycling Research Program

Dr. Richard L. Wetzel and associates in Virginia, Maryland and North Carolina have been conducting collaborative research on nutrient cycling in the Chesapeake Bay, its tributaries and the Eastern Shore of Virginia for the past decade. The studies have focused on a range of applied and basic topics that span detailed investigations of the nutrient enrichment effects on specific living resources to monitoring nutrient concentrations in sediments and water of intertidal, shoal and subtidal estuarine habitats of the lower Chesapeake Bay and its tributaries.

Research addressing the basic dynamics of nutrients in aquatic environments has involved a number of projects. Over the past few years, new techniques have been developed for using stable (non-radioactive) isotopes to study processes that control nutrient dynamics in estuarine waters. In collaboration with Dr. Howard Kator, new methods have been developed and reported for the analysis of  $N^{15}$  labelled inorganic nitrogen compounds used in research on nitrogen processing. Recently completed graduate student research projects have made significant contributions to this effort and include the work of Dr. Eric Koepfler (Ph.D. 1989) on ammonium remineralization and uptake by estuarine plankton and the work of Ms. Lori Morris (M.A. 1990) on nitrification in York River sediments and water. In collaboration with Dr. J. Zieman (UVA), inventories of the naturally occurring stable isotopes of carbon ( $^{13}C$ ) and nitrogen ( $^{15}N$ ) in sediments and waters of the James and York Rivers and the lower Chesapeake Bay have been determined and used to identify nutrient sources, sinks and recycling. In addition to these studies, the net uptake or release of nutrients and oxygen demand of sediments and waters in the York and Rappahannock Rivers have been investigated for the purposes of modeling nitrogen and phosphorus cycling.

New and continuing research in the nutrient cycling program will emphasize the development and application of new techniques for understanding nutrient dynamics including large scale computer modeling of these complex ecosystems. The ultimate goal is to couple physical-hydrodynamic processes and the biological organization of these systems at the regional level of the watershed in a framework that contributes to both better understanding of basic ecology and the management of living resources.

### Wetlands Advisory Program

During the last two years the Wetlands Advisory Program, under the direction of Dr. Carl Hershner, has reassessed its overall role in support of the Commonwealth's wetlands programs. As a result of this self-examination, additional emphasis is being placed on several program activities where scientific

expertise can provide the greatest support to resource managers. Chief among the areas receiving added attention are curriculum development for training activities in support of resource managers, the production and distribution of educational materials and technical publications, as well as new areas of research and policy development.

### Publications

The quarterly *Wetlands Board Bulletin*, edited by Messrs. Kirk Havens and Thomas Barnard, expanded to cover both tidal and nontidal wetlands along with other subjects of interest regarding the marine environment, and has been renamed *The Virginia Wetlands Report*. Distribution of the newsletter has been expanded concomitant with its broader subject areas. The first issue of the restyled newsletter contained articles dealing with nontidal wetlands in southeastern Virginia and an explanation of the risks and potential value of Japanese oyster introduction into Chesapeake Bay.

Wetlands personnel also planned, developed and began publishing a new technical report series during this biennium. The bi-monthly publication consists of two parts, a wetland plant description series authored principally by Dr. Gene Silberhorn and reports written by Wetlands personnel that deal primarily with wetlands or other environmental issues of interest to resource managers and policy makers. An additional series reporting the results of research projects was published on an unscheduled basis and is called *Technical Report - Special Edition*.

### Advisory Activities

Wetlands scientists continued their direct advisory role in the Commonwealth's shoreline permit program during the biennium by providing written technical assessments of the environmental impacts involved with 1,874 shoreline permits, 27 Environmental Impact Statements and 35 National Pollutant Elimination System permits. Also continuing during the biennium was the operation of the shoreline permitting data retrieval program. Efforts to publish the data collected for 1988-89 were nearing completion at the end of this report period. As part of VIMS advisory mandate, Wetlands personnel provided technical guidance to state resource managers at the regular meetings of the following resource management groups (which generally meet monthly): State/Federal Joint Permit Processing Group; Local Wetlands Board (31); U.S. Army Corps of Engineers (federal dredging project reviews); Virginia Department of Transportation Interagency Review Group; and the Virginia Marine Resources Commission.

### Research

Efforts designed to study the value of compensatory wetland mitigation as a management tool have continued during the last biennium. Monitoring of the eight-acre created marsh contiguous to

Goose Creek in Chesapeake measured ichthyofaunal use along with the characterization of plant community changes within the one-time borrow-pit. Additional studies concerning compensatory mitigation were completed by Mr. Walter Priest at a wetland located on U.S. Navy property adjacent to Willoughby Bay.

Mr. Thomas Barnard and Ms. Pamela Mason undertook another research effort dealing with wetland mitigation involving a survey of existing compensation sites within the tidal waters of the Commonwealth. Funded by the Coastal Resources Management Program, the study identified all existing wetland creation sites, characterized the actions taken by resource managers in utilizing compensatory mitigation as a management tool, and through field observations assessed the quality of the created wetlands. Natural systems were used for comparison where feasible. Preliminary results indicate significant vegetational differences between the artificially created wetlands and natural wetland systems studied.

Within the last year the Wetlands Program staff has initiated additional research projects. Ms. Julie Bradshaw and Dr. Gene Silberhorn have begun several studies of the structure and function of non-tidal wetlands within Virginia's coastal plain, the potential impacts of water supply development projects on tidal wetland communities in the York

River basin, and evaluation of the efficacy of current shoreline management programs.

#### **Inventories**

The publication of tidal wetland inventories for each local jurisdiction in Tidewater, Virginia has been a continuing effort. To date, inventories have been published for 30 of 36 jurisdictions within the area. During the past year Ms. Sharon Dewing and Mr. Berch Smithson revised the method of producing inventories to take advantage of the Institute's recently acquired computer-based geographic information systems (GIS) capabilities. Future wetland inventories will all be generated in the GIS format. This will allow the information to be made available to resource managers at the local and state levels in both hard copy and digital versions. The new procedures will allow generation of new, updated inventories more quickly. The objective is to support a reinventory of all tidal wetlands in the State once every five years.

During the last biennium, Dr. James Perry of the Wetlands Program staff has also undertaken studies of the distribution and abundance of rare and endangered wetland plant species for Virginia's Natural Heritage Program. This work is the first step in development of management programs for these species.



*Charlie Barr identifies wetlands soil type using a Munsell Soil Color Chart.*

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## DIVISION OF CHEMISTRY AND TOXICOLOGY



*Barbara Rutan works under the supervision of Dr. Mohammed Faisal.*

**T**he Division of Chemistry and Toxicology, headed by Dr. Robert J. Huggett, has been involved with numerous studies related to the health of tidal waters of the Commonwealth, the Chesapeake Bay, the nearby coastal ocean, and aquatic biota. Research efforts include: analytical and physical chemistry of pollutants, atmospheric deposition, fate of pollutants in the marine environment, biochemistry, cytology, histology, immunology, pathobiology and toxicology.



### **Analytical Chemistry**

Under the direction of Dr. Michael A. Unger, this group focused on the development and application of state-of-the-art techniques for the analysis of hazardous chemicals in the estuarine environment. The analytical research program also conducted chemical analyses to assess the long-term trends or fate of chemical pollutants in Chesapeake Bay.

Monitoring for Kepone in the James River has been ongoing since 1975 when it was first discovered in the river near Hopewell, Virginia. By analyzing fish, sediment and water samples, Messrs. Harold Slone and James Greene have learned that concentrations of Kepone in fish samples have decreased over the last fifteen years as pesticide-laden sediments have been buried. Though concentrations are generally below the Federal Action Level (0.3 ppb), individual samples occasionally exceed this limit.

Tributyltin (TBT) is a toxic component of antifoulant paint formerly in common use in the Chesapeake Bay region. In 1987, Virginia enacted legislation limiting the use of TBT paints on recreational watercraft. This legislation was due in part to early research at VIMS, where new analytical techniques were developed to detect TBT at low concentrations in water, sediment and shellfish. The TBT research effort showed that the highest TBT concentrations occur in the areas of greatest recreational boat activity.

TBT monitoring, under the direction of Ms. Ellen Travelstead, has shown decreasing levels of TBT at most stations since the legislation was enacted. Concentrations in the water column are decreasing slowly as older sediments are overlain. Even so, low levels of TBT continue to be released into overlying waters. Animals have been found with TBT concentrations many orders of magnitude higher than adjacent water samples, and morphological changes in snails, attributable to TBT, have been noted.

### **Atmospheric Deposition Research**

Dr. Rebecca M. Dickhut and colleagues in Virginia, Maryland, and Delaware have initiated research to examine the atmospheric deposition of toxic contaminants to the Chesapeake Bay. Chesapeake Bay Atmospheric Deposition (CBAD) monitoring sites were established at Wye Mills and St. Mary's County, Maryland, and Mathews County, Virginia. Precipitation, atmospheric aerosols and vapor are being sampled for concentrations of selected organic contaminants including polycyclic aromatic hydrocarbons and polychlorinated biphenyls, trace elements, and major ions. Researchers will evaluate the annual input of chemical contaminants to the Chesapeake Bay via the atmosphere. Information generated from the CBAD study is expected to be used to develop manage-

ment practices for the Chesapeake Bay and regional air pollution control.

Dr. Dickhut, Messrs. Brian Hancock, John Bense (Williamsburg Campus), William Mathews and Ms. Suzanne Alexander have designed and fabricated a precipitation sampler for organic pollutants in rainfall. The new sampler is a fully automated precipitation collector and weather monitoring station and represents a significant improvement over previous wet deposition samplers.

Dr. Dickhut's research group is also involved in examining the physical-chemical properties of organic pollutants which control partitioning and transport in the environment. Dr. Dickhut and Elizabeth H. MacDonald have developed methods for measuring aqueous solubility, vapor pressure, and sorption coefficients of chemical contaminants. Development and calibration of quantitative-structure-property-relationships (QSPRs) for predicting physical-chemical properties through molecular modeling are an integral part of this research. Dr. Dickhut, working with scientists at Monsanto and the University of Wisconsin, has been successful in developing an improved QSPR between aqueous solubility and total molecular surface area.

### **Biochemistry**

Under the "Toxics Research Initiative" supported by the Commonwealth of Virginia, Dr. Peter A. Van Veld conducted tests on the biochemical effects of pollution exposure on aquatic animals. Once in an organism, many chemical contaminants are susceptible to transformation by various xenobiotic metabolizing enzymes. Metabolism by cytochrome P-450 monooxygenases, glutathione transferases and glucuronosyl transferases generally result in detoxification and enhanced elimination of the foreign compound. However, metabolic activation can cause some compounds to become carcinogenic.

During 1989-90, Ms. Donna Westbrook and Dr. Wolfgang Vogelbein joined in studies of altered levels of xenobiotic metabolizing enzymes in hepatic tumors of estuarine fish and on genetic differences in the responses of different populations of fish to environmental contaminants. Studies on the role of the intestine in metabolism of foreign compounds are continuing. Most recently, Van Veld and colleagues, Mr. E. W. Warinner and Drs. Anne Weeks and Mohamed Faisal have been involved in evaluating the response of various biochemical, immunological and cellular biomarkers in fish exposed to pulp mill effluent at the National Council of Air and Stream Improvement (NCASI) warm-water stream experimental station in New Bern, North Carolina.

### **Cell Culture**

Dr. Faisal's laboratory has been successful in establishing primary hepatocyte cultures of several Chesapeake Bay finfishes such as spot (*Leiostomus*

*xanthurus*), Atlantic croaker (*Micropogonias undulatus*), oyster toadfish (*Opsanus tau*), mummichog (*Fundulus heteroclitus*), hogchoker (*Trinectes maculatus*), and Atlantic menhaden (*Brevoortia tyrannus*). The effects of toxicants on these cells have been studied using cytotoxicity, genotoxicity and synthesis of macromolecules. These three parameters were shown to be sensitive indicators to toxic effects of PAH at the cellular and subcellular levels. Three cell lines—MML from a hepatocellular carcinoma of mummichog, SS from spot spleen, and SLW of spot liver—have been established.

Graduate student Christopher Williams is involved in a study of the characteristics of lens cells of spot and Atlantic croaker. Cultures of lens epithelial cells have been established. Examinations of lens cell responses to various chemicals are underway.



The Transmission Electron Microscope being used by Patrice Mason is an important research tool.

### Environmental Chemistry

The "Pilot Toxics" project, in cooperation with the Virginia Water Control Board (VWCB), was completed in 1988. Major participants were Drs. Rob Hale and Craig Smith supported by Mr. George Vadas, Ms. Ellen Harvey and Ms. Deborah Anderson. Analytical techniques were developed and applied for the detection of hazardous organic compounds in aquatic environments. The intent of the program was to detect chemical pollution before concentrations accumulated to effect levels. Effluents from over 30 industrial and municipal dischargers and associated sediments and shellfish were examined. In addition to polycyclic aromatic compounds (PAH), polychlorinated biphenyls (PCB), and organochlorine pesticides, a number of rarely reported compounds were detected such as nonylphenols, nitrogen heterocyclics and polychlorinated terphenyls (PCT). The PCT, found in very high concentrations in estuarine sediments and shellfish, had not previously been detected in the United States. The source of PCTs, which are

similar in structure to PCBs, was traced to a large aeronautics complex. Additional studies are being conducted by Ms. Kathryn Gallagher, a graduate student, on the distribution and concentration of PCT in the biota and sediments of the area. Work is also being conducted on the bioaccumulation of various compounds found in effluents.

Drs. Fu-Lin Chu and Hale are examining the influence of exposure to pollutants on the susceptibility of disease in aquatic biota. The test organism is the American oyster; the disease is *Perkinsus marinus* which has severely impacted oyster populations in the lower Chesapeake Bay. A widely held, yet untested, hypothesis is that pollutant exposure has increased the oyster's susceptibility to infection. The new study, sponsored by the Sea Grant College Program, is designed to test this hypothesis.

Graduate student Robert Mothershead, II completed a project examining the levels of PAHs and PCBs in blue crabs collected from the heavily polluted Elizabeth River.

Ms. Jennifer Gundersen, a doctoral candidate, is developing a methodology to quantify chlorinated components in pulp mill effluents. Pulp mill effluent consists of a complex suite of compounds generated during the bleaching of wood fibers used in paper production. Ms. Gundersen's techniques will be applied to understanding the fate and transport of pulp mill effluents in the waters of the Commonwealth.

Dr. C. L. Smith is developing the Virginia Toxics Data Base. This project, supported by VWCB, involves collecting, assembling, and storing a wide spectrum of chemical analytical data generated by VIMS and VWCB over the last 15 years. The format will allow direct on-line retrieval access by modem.

The occurrence of malignant tumors in fish from highly PAH polluted areas makes it desirable to study details of PAH metabolism. Since not all PAH metabolites are carcinogenic, it is necessary to develop methodology to allow relatively simple determinations of metabolite structures. Drs. Rudolf Bieri and John Greaves have approached this problem using mass spectrometry with soft ionization methods combined with liquid sample introduction. The methods are direct liquid introduction (DLI), thermospray (TS) and fast atom bombardment (FAB). Since 1988, the FAB method of ionization has been investigated for hydroxylated benzo(a)pyrene metabolites as well as their glucuronide and sulfate conjugates. Of all ionization methods used so far, FAB provided the most useful spectra and sensitivities for identifying PAH metabolites.

Organochlorine compounds are frequently-occurring, highly-persistent pollutants in the environment. Examples include the polychlorinated biphenyls (PCBs) and insecticides such as chlordane

and DDT. Dr. Greaves has undertaken a variety of projects in which mass spectrometry has been used for analysis of organochlorine compounds. The studies have included: identification of PCB and DDT in two coelacanths (*Latimeria chalumnae*); studies on polychlorinated terphenyls in the southern Chesapeake Bay; investigation of the mass spectrometric fragmentation behavior of PCB in negative chemical ionization; and identification and monitoring of PCB in effluents from the wastewater treatment facility of an industrial plant.

#### **Chemical Transport**

Dr. W. G. MacIntyre's research on organic contaminant transport by groundwater has been supported by the U.S. Air Force. In association with this investigation, graduate student George Vadas is studying hydrocarbon mixture solubilities. A major groundwater transport test facility has been established at Columbus Air Force Base, Mississippi and is now being used to test some transport models in a heterogeneous, anisotropic aquifer.

Dr. MacIntyre has also conducted preliminary measurement of nutrient inputs to Chesapeake Bay via groundwater and is involved with determining the homogeneous and heterogeneous catalysis of triazine herbicides. A portion of the work is being done by graduate student Laurence Libelo. This study is particularly important because of potential implications regarding the fate of submerged aquatic vegetation (SAV) in Chesapeake Bay.

#### **Electron Microscopy/Histopathology**

Dr. Wolfgang Vogelbein's research on histopathology involves a number of projects. During a fish health survey in the summer of 1989, tissues of some 700 fish of eight species from several Chesapeake Bay localities were examined microscopically. In an Elizabeth River population of mummichog (*Fundulus heteroclitus*) a very high prevalence (35%) of hepatic and other neoplasms was identified in adult fishes. Neoplasms were linked to chronic exposure of the fish to creosote-related toxic wastes from a nearby active wood treatment facility. Characterization of the predominant hepatocellular lesions has been completed, and detailed classification of these, as well other tumors, is underway. Mr. David E. Zwerner, Ms. Patrice Mason and Ms. Patricia Blake are involved in the research.

Dr. Vogelbein and Mr. Zwerner are studying the progression of chemically induced hepatic neoplasms in the mummichog using Nuclear Magnetic Resonance Imaging and Image Analysis (morphology/stereology) with Dr. Gassner of the U.S. Department of Agriculture. Drs. Morris H. Roberts and Peter A. Van Veld are collaborating with Vogelbein in experimental exposure of laboratory-reared *F. heteroclitus* to creosote-contaminated Elizabeth River sediments. Their objective is to establish the

cause-and-effect relationship between the neoplasia and the exposure to xenobiotic contaminants. Dr. John Fournie of EPA Gulf Breeze and Vogelbein are studying the ultrastructure of pancreatic neoplasms and exposure to xenobiotic contaminants.

Research on toxic-induced responses in mummichog tissues includes two additional projects. The first, with Drs. Van Veld and Smolowitz (of the Woods Hole Oceanographic Institution), involves evaluation of Phase I and Phase II enzymes in hepatic neoplasms using biochemical, histopathological, and immunohistochemical methods. A second project is development and morphological characterization of cell lines derived from mummichog hepatocellular carcinoma.

#### **Immunology**

Dr. Beverly A. Weeks, Mr. J. Ernest Warinner, and graduate students Kenneth R. Seeley and Karen K. Reay worked on immune system assays as potential biomarkers for the effects of toxicants on fish species. They have shown that fish which have been exposed to polynuclear aromatic hydrocarbons (PAH), both in the field (Elizabeth River, VA) and in the laboratory, show significant changes in the immune activity of kidney macrophages (cells which destroy foreign substances). Various aspects of macrophage activity, including phagocytosis, chemotaxis, pinocytosis and chemiluminescence have been investigated and shown to be affected by exposure of the fish to toxic chemicals. Responses were suppressed or elevated depending on the species and activity tested. All alterations, however, could be reversed when fish were held in clean water. Recently, a simple technique for assaying phagocytic activity of fish macrophages was developed. This method utilizes yeast cells stained with Congo Red as phagocytic targets and a spectrophotometric determination of the endpoint of phagocytosis. This technique has been shown to be a sensitive indicator of immunocompetence in fish taken from various sites in the Chesapeake Bay. The laboratory is currently conducting experiments to determine the cellular immune status of tumor



Anne Weeks and Ernie Warinner remove a fish tissue sample.



bearing fish, as well as characterizing the anti-tumor responses in healthy as well as carcinogen-exposed fish.

Dr. M. Faisal and his group have studied the lymphocyte activation of spot, Atlantic croaker, oyster toadfish, hogchoker and mummichog to determine the correlation between the degree of lymphocyte activity as a measure of proliferative responses, mitogens, and sediments containing PAH. Additional studies involved measuring differences in the abilities of these fishes to synthesize DNA, RNA and protein when exposed to "reference" York River and contaminated Elizabeth River sediments.

An additional project, with Dr. W. Vogelbein, involves comparison of the immunological competence of tumor-bearing mummichog (*Fundulus heteroclitus*) versus "healthy" ones.

#### **Pathobiology**

Several projects in this area of research have been pursued under the Commonwealth's Toxics Research Initiative. Dr. W. Hargis, with Messrs. J. A. Colvocoresses, J. E. Warinner, D. E. Zwerner, former graduate student Dr. D. A. Thoney and others, investigated the effects of Elizabeth River sediments and sediment-influenced water on the health, abundance, and distribution of trawl-captured finfishes. The Catch-Per-Unit-of-Effort (CPUE) was lower at the severely contaminated stations as was the biomass. Seasonal abundance, productivity and size-class distribution within the Elizabeth River are also under study.

Research on effects of exposure to contaminated Elizabeth River sediments on the eyes of three sciaenid fishes continued. A number of lesions, such as externally-visible cataracts and hyperaemia as well as internal disorders, including retinopathy, hemorrhagic vitreous and enlarged and engorged choroid rete, were examined. Dr. Hargis, Mr. J. E. Warinner, and graduate student Karen Reay collected and examined 398 mummichog from a PAH-contaminated Elizabeth River site. Some 42 (or about 11%) external lesions were observed on the collected fish. Of those lesions, 6.5% were parasitic, 2.0% were traumatic and 2.0% (eight individuals) were neoplastic. Histological study of the neoplasms revealed six frank or incipient oral papillomas, one with a malignant schwannoma of the right pectoral fin and one with a capillary-type hemangioendothelioma of the left gill chamber. A report on these findings was published in 1989.

Research on diseases of the eyes of fishes, especially those involved in aquaculture, breeding facilities and display aquaria, resulted in preparation of the review manuscript "Disorders of the Eye in Finfish." With Dr. Thoney, the review paper

"Monogenea (Platyhelminthes) as Hazards for Fish in Confinement" was prepared.

#### **Radiochemistry**

Radiochemist J.E. Warinner collaborated with Dr. Robert J. Diaz in analyzing sedimentation rates in areas of the Chesapeake Bay, Potomac River, Rappahannock River, York River and Poquoson River. In doing so, 754 core sections were counted on the intrinsic germanium gamma detector for Lead-210. Also in collaboration with Dr. Diaz, rain water samples and sediment samples were analyzed for their content of Beryllium-7 in order to study the perturbation of bottom sediments. Graduate student Julia Wilcox counted some 50 sediment core sections for Cesium-137 to obtain sedimentation rates in a marsh area in connection with her thesis research.

#### **Toxicology**

During 1988-89 testing of a potential marine antifoulant was initiated by Dr. M. H. Roberts, Jr. under contract to Rohm and Haas Company. Following development of an analytical method by Dr. R. Hale, toxicity testing was initiated with mysids, oysters (embryo/larvae and larvae) and fish. The instability of the test compound precluded meeting certain stipulations concerning variability of the exposure concentration in flow-through tests with mysids and fish.

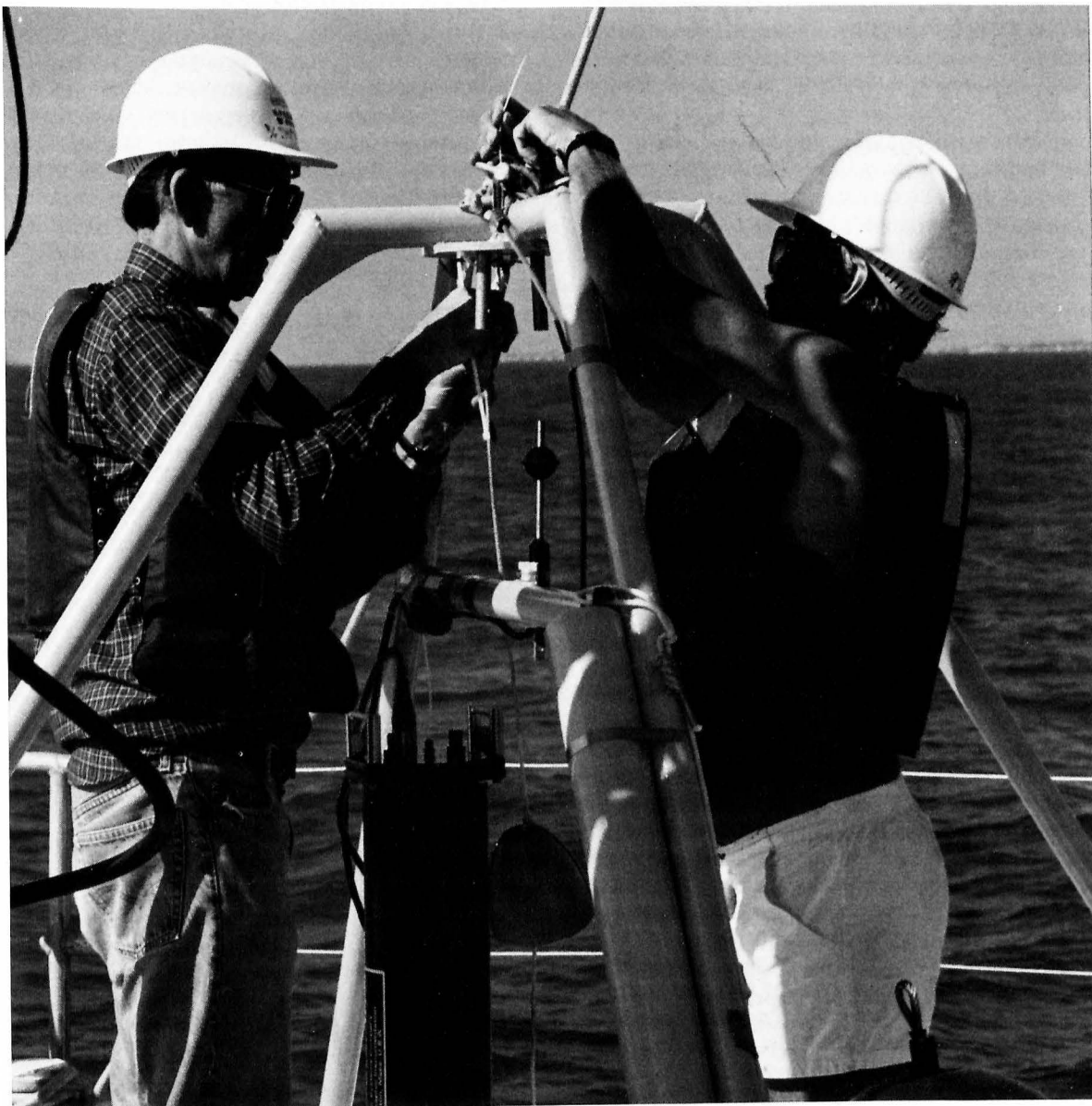
In 1989-90, Dr. Roberts expanded the Rohm and Haas studies to evaluate the rate of die-away of the test compound and to determine the relationship of die-away to salinity, presence of algae, and sterilization by autoclaving, filtration, and ultraviolet light. There was no demonstrable effect of salinity on the rate of die-away of the test compound, but elevated concentrations of algae did increase the die-away rate substantially. All three sterilization methods were effective at reducing die-away of the test compound, with slightly better results achieved with filtration and autoclaving than with ultraviolet light.

Studies of the effects of the organophosphate pesticide, diazinon, on juvenile oysters were completed by graduate student Ruth Williams. This study included determination of the acute toxicity and examination of the effect of diazinon on acetylcholinesterase activity.

As chairman of Committee E47 of the American Society for Testing Materials, Dr. Roberts has established several new task groups to address methods in areas not previously considered. Methods are under development for various West Coast marine species. He also coordinated the development of guides for laboratory test methods with behavioral or other sublethal endpoints.

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## DIVISION OF GEOLOGICAL AND BENTHIC OCEANOGRAPHY



*John Boon and Robert Gammisch prepare a benthic tripod for deployment.*

**T**he Division of Geological and Benthic Oceanography incorporates scientists and programs concerned with the physical and biological factors affecting the transport, deposition and resuspension of sediment, geologic history of estuarine bodies, the forces shaping shorelines and their evolution, and the ecology and resource value of benthic organisms.

## Geologic History and Sedimentary Environments

The program of study of the geological history of Chesapeake Bay and the inner shelf recently has been, in part, concerned with the origin of particular sand bodies on the shelf and with better defining the three dimensional network of filled paleochannels near the bay's mouth. Master's thesis work by Mr. James Dame has elucidated the history and mode of formation of a previously undescribed shoal, and ongoing work by Mr. Carl Hobbs has provided a continuation of earlier works concerning the Quaternary stratigraphy of the inner shelf.

In May 1990, Dr. Maynard Nichols initiated a five-year effort to synthesize the status of bottom sediments, sediment contaminants, and sedimentary processes of the nation's estuaries. A comprehensive computerized data base is under development, charts of sediment distributions are being compiled, and sediment budgets are being evaluated. The synthesis will permit regional assessments of sediment flux into or through estuaries and indicate the susceptibility of different estuaries to pollution. The study is sponsored by the NOAA Strategic Assessments Division, Rockville, Maryland.

As a joint effort in collaboration with Dr. Gerald Johnson, William and Mary Department of Geology, and Dr. Pam Peebles, Virginia Department of Transportation, Dr. Nichols is comparing modern and ancient sediments of the James River to develop facies models. These are of use in understanding the formation of estuarine sediment strata and to assist in predicting occurrences of petroleum reservoirs in similar ancient rocks. Results indicate the James develops a systematic tripartite facies arrangement filling the path of the pre-Holocene fluvial drainage. The facies reflect the landward evolution of the estuary following the sequence: fluvial to fluvial estuarine to estuarine to marine estuarine.

## Benthic Ecology

Research of the benthic ecology group, headed by Drs. Robert Diaz and Linda Schaffner, spanned a wide range of subject matter from invertebrate taxonomy, with the description of one new species and the addition of many new species records, to investigations into the functional aspects of benthic communities, to international cooperative research with Sweden on the effects of oil in the marine environment.

## Chronic Effects Of Seasonally Low Dissolved Oxygen On The Resource Value Of The Bottom

While a great deal is known about the distribution and occurrence of no (anoxia) and low (hypoxia) dissolved oxygen waters in the Bay, what still needs to be known is how anoxia, hypoxia, productivity and fisheries are all linked. From a comprehensive study in the lower York River VIMS researchers were able to understand how the

seasonal phenomenon of hypoxia affects the use of bottom habitats by fish and how the benthos react to hypoxia. The methods included cores for benthic communities, X-ray for biogenic structures, surface and sediment profile (SPI) cameras for evaluating rapid reactions of the communities, measurement of growth and production, trawling for fish communities and evaluation of fish stomach content, and a radio-telemetry environmental data buoy to continuously monitor oxygen conditions.

Because of the complexity and quickness with which oxygen concentrations can change, the acquisition of real-time data on oxygen concentrations was essential for testing hypotheses regarding the effects of hypoxia and anoxia on living resources. This is particularly true in areas, such as the York River, that fluctuate between hypoxia and normal oxygen concentrations. Real-time data on oxygen concentrations were transmitted by the data buoy from the field to the laboratory every 20 minutes; this allowed us to coordinate the field sampling program. This was particularly important for examining behavioral changes of the macrobenthos and following the changes in feeding habits of bottom dwelling fishes.

Response of the benthos to oxygen stress was found to be a function of the severity of the hypoxia in terms of oxygen concentration and duration of low oxygen. Brief (on the order of days) and extended (on the order of weeks) periods of hypoxia did elicit a quick response from the benthos in terms of behavioral changes. Changes in the burrowing behavior of organisms was seen under mild hypoxic conditions with a shallowing of species depth distributions during hypoxia followed by a return to normal burrowing depth after the hypoxic event. During hypoxic events many different species were seen laying on the sediment surface. These two behavioral changes, decreased burrowing depth and exposure at the sediment surface, as a function of hypoxia were found to make organisms more susceptible to predators, particularly opportunistic prey species that have a tolerance to low dissolved oxygen.

Consequently, periodic mild hypoxia may be an important factor in making biomass more readily available to bottom feeding fish and in limiting the distribution of deep burrowing infauna. However, hypoxia may also alter species interactions and influence the functional role played by benthos. For example, the ability of macrofaunal assemblages to move and mix sediment may be reduced, which in turn will mediate benthic nutrient remineralization rates. Future work on the effects of hypoxia and anoxia will focus on how altered function of the benthos relates to water column dynamics, in particular to eutrophication.



### Benthic Habitat Assessment And Classification

Much of the development activity in the Chesapeake Bay and critical national environmental issues involve subtidal bottoms. Bottom sediments, and their associated biota, are important because they are the final sinks for almost everything that enters the estuarine and marine waters. To meet the challenge of managing and regulating activities that ultimately could affect the productivity and yield of estuarine and coastal systems, the benthic research group has developed a series of habitat evaluation methods that are being applied to state and national environmental problems. The two most recently developed methods are the benthic assessment procedure (BAP) and sediment surface and profile imaging (SPI). These are both rapid assessment procedures designed to provide data on benthic habitat quality in days to weeks, as opposed to months for traditional methods.

BAP involves traditional sample collections for benthic communities, both phylum taxonomy and wet weight biomass of major groups for rapid sample processing, and functional group recognition of large individuals by depth fraction, top (0-5 cm) and bottom (5-15 cm), of sediment. The basic scientific premise of BAP is that the quality of the

habitat can be determined by the presence of certain types of organisms (in a sense indicators) and the proportion of living biomass in the bottom fraction. A sample that contains a large proportion of biomass in the bottom fraction is indicative of a higher quality habitat with longer lived species that have not been exposed to excessive stress. A sample that contains a large proportion of biomass in the top fraction is indicative of lower quality habitat with unstable populations dominated by small opportunistic organisms on the sediment surface. Work continued on the development of BAP and on how benthic habitat quality relates to productivity and fisheries yield.

SPI is an *in situ* photographic remote sensing technique that involves a combination of standard underwater cameras for imaging the sediment surface, and sediment profile cameras for imaging subsurface sediments. A combination of visual and computer image analyses techniques are then used to generate a data set for classification of benthic habitats. SPI can quickly (on the order of days) define scales (from 10's of meters to kilometers) of spatial patterns in biological, sedimentological, geochemical, and physical energy gradients in benthic habitats. The scientific staff has used SPI extensively to document the effects of dredged material disposal and hypoxia on bottom communities, to map benthic habitat gradients throughout the Bay, to identify suitable habitat for the overwintering of blue crabs, and to assess potential impacts from various projects (for example sand mining for beach nourishment). Future work with SPI will be aimed at developing correlations between the images and benthic habitat quality to provide field validation to our interpretations.

### International Research On The Effects Of Oil Pollution

A joint Swedish-American research program was initiated between the University of Goteborg and the College of William and Mary to do cross-system comparisons and investigate the responses of the benthos to oil pollution. Initially, the program will focus on heavily impacted areas in both countries to determine common and differential responses of the benthos. In 1990 surveys were conducted in the Southern Branch of the Elizabeth River, known to be heavily contaminated, using BAP and SPI to characterize the benthos. Similar data will be collected from a small Swedish fiord that is the site of an oil refinery. This type of cross-system comparison is very robust for understanding mechanisms that cause benthic habitat quality to change.

### Benthic Boundary Layer Studies

Several related activities focused on the general problem of improving our understanding of the dynamics of bottom boundary layers and related processes of sediment erosion, transport, and deposi-



*The sediment surface and profile imaging system.*

tion. State-of-the-art field instrumentation used in these investigations was obtained largely via funding provided by private sector contributions. Funding for the various studies was provided by the National Science Foundation, the Minerals Management Service, NOAA-Sea Grant, the Office of Naval Research via Louisiana State University, and VIMS general funds.

Dr. Jerome P.-Y. Maa has concentrated heavily on the dynamics of cohesive sediments. He is especially interested in the exchange processes that occur at the water-mud interface including how the sediment is eroded or deposited and at what rate. Previous studies have suffered from the criticism that they seriously disturb the sediment properties because they have to sample the sediment and do the tests in laboratories. Now Dr. Maa is trying to conduct experiments with minimum disturbance of the original sediment properties. To meet this requirement, he has designed and is completing fabrication of an annular sea-bed flume that will bring the instrumentation to the sea floor and perform the tests *in situ*. The results from this flume will enable scientists to improve the prediction of sediment and pollution transport.

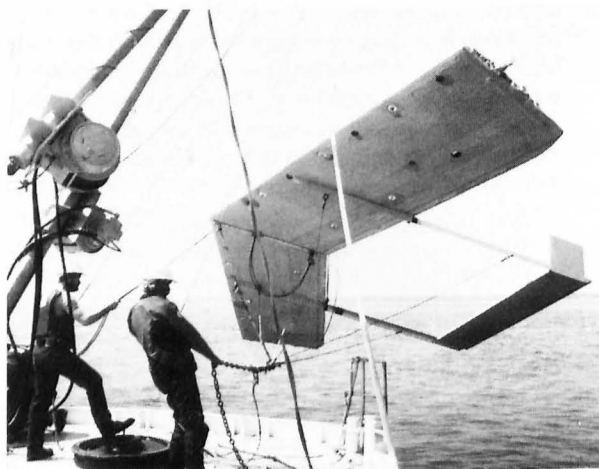
A study aimed at explaining the processes responsible for transporting sediment across the shoreface region seaward of the surf zone was completed. The results show that the upper shoreface is highly responsive to moderate storms and that bed elevations may fluctuate by an order of 10 cm over time intervals of a few hours. Suspended sediment concentrations at elevations of about 10 cm were observed to vary from less than  $0.1 \text{ kg m}^{-3}$  under fair weather conditions to  $1\text{--}2 \text{ kg m}^{-3}$  under moderate swell conditions to over  $10 \text{ kg m}^{-3}$  during storms. Cross-shore mean flow velocities ranged from  $<1 \text{ cm s}^{-1}$  during fair weather to  $>20 \text{ cm s}^{-1}$  during storms; oscillatory flows were on the order of  $10 \text{ cm s}^{-1}$  during fair weather and  $100 \text{ cm s}^{-1}$  during storms. Most significantly, mean flows were seen to dominate offshore fluxes during the storm and to contribute significantly to onshore and offshore flux during fair weather and moderate energy. A related study of the processes of gravity-driven sediment transport off the mouth of the sediment-charged Yellow River in China was also completed.

A study was carried out to examine the feasibility of utilizing low-cost moored wings to ventilate hypoxic benthic environments. Modeling and the construction and test deployment of four full scale wings was completed. The wings, situated just above a pycnocline by means of a swivel mooring, produce upward lift and downwashing vortices thereby enhancing vertical mixing. Results show that the wings can readily yield the necessary Reynolds numbers to cause intense vortices and vertical mixing. The rate of decay of wing-induced vortices increases with increasing stratification (increasing Brunt-

Vaisala frequency). The necessary wing span and chord length increase as vertical density stratification increases and as current velocity decreases. The wings used in the study had a span of 6 m.

### Comprehensive Coastal Inventory

The Virginia Institute of Marine Science has completed the first year of a long-term project designed to map and catalogue various components of the 5,000 miles of tidal shoreline in Virginia. Initial investigations, under the direction of Dr. Suzette M. Kimball, have been focused on the geographic



Deploying a "water wing."

region bounded by the Potomac and Rappahannock Rivers (Northern Neck). Information pertaining to shoreline positions, recent changes in shoreline positions, boundaries of tidal and non-tidal wetlands, sediment characteristics, and shore zone profiles have been collected, digitized and stored in a vector-based geographic information system (GIS), and analyzed to determine regional patterns of shore zone characteristics. These studies are being used to address management issues pertaining to natural pressures, such as potential sea level rise, and anthropogenic pressures created by development in the coastal zone.

The primary focus of the Coastal Inventory is to delineate environmentally sensitive areas for management considerations. The General Assembly recognizes the utility of the Coastal Inventory to efforts of several state agencies, including the Chesapeake Bay Local Assistance Department; various boards and commissions, including the Chesapeake Bay Local Assistance Board and the Board for the Conservation and Development of Public Beaches; and the partner localities of Tidewater, Virginia.

The initial year of data collection effort has been limited geographically to the four counties commonly referred to as the Northern Neck: Westmoreland, Lancaster, Richmond, and Northumberland.

Data acquisition methodologies, storage and retrieval techniques, and applications software were tested. Of the 14 layers of data targeted for eventual inclusion, nine primary coverages were completed in-house. These include: tidal wetlands inventories, first order streams, transportation network, shoreline position (3 scales of coverage: 1:1,000,000; 1:24,000; 1:5,000), shoreline erosion/accretion, dune/bluff presence and characteristics (qualitative), nearshore bathymetry (limited to sub-aerial and intertidal areas), sediment characteristics, and the distribution of shoreline structures (qualitative). In addition, nearshore land use and elevation data have been supplied by the Virginia Department of Conservation and Recreation. Quantitative assessments of watershed boundaries and wind and wave climatology are underway. An assessment of state and public claims to coastal lands was completed for Accomack County.

In less than one year of operation the Comprehensive Coastal Inventory has demonstrated its utility to a number of users. The inventory database has been queried to determine the history of shoreline configurations in portions of Northumberland County to provide background information relating to designations of protection areas. Similar questions have been posed for areas in Mathews County. The aerial imagery, both vertical and video, are being used to assess patterns of land use and resource distribution for permitting agencies. Similarly, the sediment information augments an inventory of offshore sediment resources and has been used to answer questions pertaining to the suitability of certain offshore sand deposits relative to proposed onshore disposal areas.

#### **Sand Resource Exploration**

Commonwealth cities fronting the lower Chesapeake Bay and open Atlantic are facing increasing pressures on beach resources as a result of economic development and tourism. Upland sources of beach quality sand have been depleted in recent years. Consequently, the state has sponsored an extensive exploration program to develop offshore areas as sand reserves. In recent years, over 1,000 track miles on the inner shelf of Virginia and in the lower Chesapeake Bay have been surveyed using high-resolution seismic and side-scan techniques. Data collected from the geophysical records were correlated with sediment cores and surface samples. Over  $10^8$  m<sup>3</sup> of clean beach quality sand lying in recoverable configurations have been identified. In addition, benthic resource evaluations of probable mining areas have been completed. These surveys have made it possible to recommend sand reserves that might be recovered with the minimum amount of environmental disturbance.

As a result of the sand resource exploration efforts, new information about the Quaternary history

of the inner shelf has been acquired. Of particular interest are large, isolated, amorphous sand shoals that exist in concert with complex geometries of Pleistocene and early Holocene channel deposits. These sand shoals do not fit the classical models of linear shoal field deposits. Corresponding features located seaward of the mouth of the Delaware Bay estuarine system have been recognized. A cooperative program with the Department of Geophysics at the University of Delaware has been initiated to study sand bodies associated with the seaward limits of large estuaries.

#### **Chesapeake Bay Wave Climate**

Scientists of the Division of Geological and Benthic Oceanography, in cooperation with the Virginia Department of Conservation and Recreation, have pursued a systematic study of the hydrodynamic processes affecting recreational, shoreline and benthic resources in the coastal zone. A key element in that study has been the characterization of the wave climate within lower Chesapeake Bay, a region broadly influenced by surface water waves generated both locally and in the adjacent Atlantic Ocean. Wind waves and swell generated during storms are often the primary forcing responsible for: 1) shoreline erosion; 2) damage to property and coastal structures; 3) recreational boating hazards; 4) scouring and dispersal of benthic sediments including dredged materials placed on the bay floor and inner shelf. Due to extensive channel deepening to improve port access within the bay, nearly 100 million cubic yards of dredged sediment are likely to be placed at various designated disposal sites over the next several decades.

Past knowledge of basic wave properties such as height, period and direction has been made conspicuous by the lack of precise observational data. In the past, the information available to coastal scientists, engineers and resource managers has been restricted to synthetic wave parameters generated by computer models, using observed wind data to "hindcast" the waves. Problems associated with this approach became very apparent following recent completion of a year-long series of continuous wave measurements by a VIMS wave gage installed near Thimble Shoals Light. Observed waves proved to be much more complex than anticipated (two separate "modes" of period and direction were observed in 1988 and 1989) and strong tidal modulation affected both wave height and period. An observational program is essential if reliable wave statistics (normal as well as extreme values) are to be compiled for the Chesapeake Bay region. Wave models, to be useful, must have data that not only permit their calibration but also achieve a clear understanding of the complex wave processes being modeled.

Future needs include not only the development of a database of historical wave information for re-

search and planning purposes but "real-time" observational capabilities as well. VIMS is presently developing a prototype directional wave gage to be installed at the Chesapeake Light Tower seaward of the bay entrance. This system ultimately will use cellular telephone technology to transmit wave information at hourly intervals to a central computer at VIMS. There it can be quickly accessed by users with dialup capabilities. With further modeling development, it should be possible to obtain essential wave characteristics not only at the light tower during major storm events, but to produce near-real-time forecasts of wave parameters at selected sites inshore of this station with continual updating as required. The need for near-real-time capability is not restricted to storm events, however. In the event of a major oil spill, the trajectories of "plume" movement will be greatly affected by the existing wave field and short-term forecast models will again need actual wave data including directional information.

### Shoreline Studies

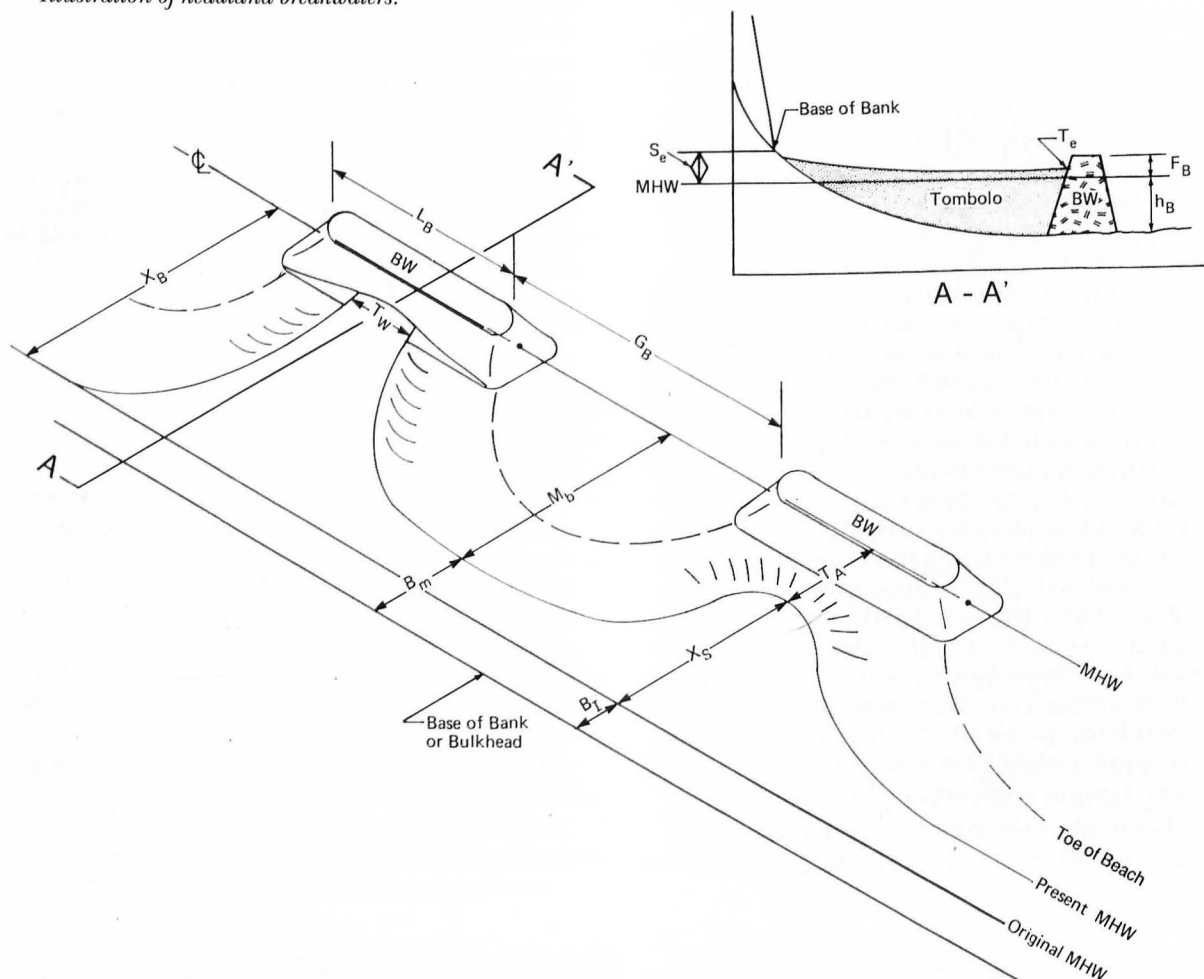
Shoreline erosion in the Chesapeake Bay estuarine system causes the permanent loss of uplands and marsh shorelines as well as contributes to sediment and nutrient loading into Bay waters. Traditional methods used to abate this process include

bulkheads, stone revetments and groins. For the past three years VIMS has monitored and evaluated the use of headland breakwaters to manage shoreline erosion through a study funded by the U.S. Army Corps of Engineers and the Virginia Division of Soil and Water Conservation. Monitoring efforts included quarterly profiling, aerial photography, sediment analyses and computer modeling. Headland breakwaters are offshore structures, usually made of stone, and built to retain beach fill which in turn reduces wave action against upland areas.

The results of the Chesapeake Bay Shoreline Study have provided minimum design criteria for future headland breakwater installations. The breakwater length, spacing and distance offshore are functions of wave climate and desired backshore beach width. Alternating breakwater headlands and pocket beaches also provide a stable substrate upon which marsh grasses may be planted. This vegetative fringe helps further reduce incoming wave energy and also traps sediments and nutrients originating from upland storm water runoff.

Each proposed shoreline project must be evaluated with respect to its individual situation in terms of land use and wave climate.

*Illustration of headland breakwaters.*





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## DIVISION OF PHYSICAL OCEANOGRAPHY AND ENVIRONMENTAL ENGINEERING



*Members of the plankton research team retrieve in situ photography system.*

**T**he Division of Physical Oceanography and Environmental Engineering, headed by Dr. Bruce Neilson, includes a diverse group of scientists, all of whom are studying issues greatly affected by water movement and transport processes. The biologists' efforts have emphasized application of state-of-the-art technology, while engineering scientists continue to develop and use mathematical models to describe flows, simulate natural processes, and to use these models to assist resource and water quality managers.

### Hypoxia in Virginia Estuaries

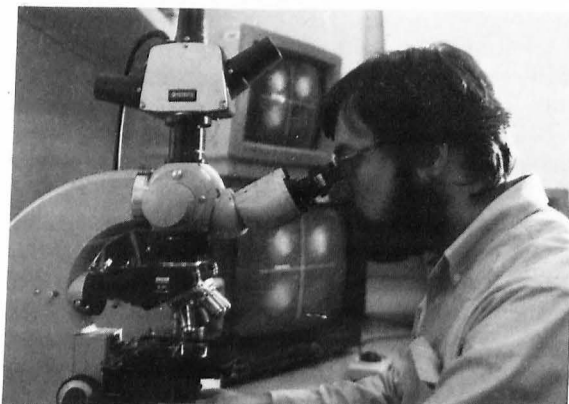
Past studies indicated that chronic and persistent hypoxia in the saline portions of Virginia subestuaries of the Chesapeake Bay was largely restricted to the 'deep holes' located near the mouths of the Rappahannock and York rivers. It was also observed that hypoxic conditions occurred most frequently in the Rappahannock River and rarely occurred in the James River, even though it receives the heaviest wastewater loadings among the Virginia subestuaries. Through the hypoxia project of the Chesapeake Bay Initiative Research Programs a better understanding of the spatial and temporal variabilities of hypoxic conditions in the Virginia subestuaries was achieved during 1988-1990. The hypoxic condition persisted in the bottom waters of the Rappahannock River throughout the summer months. It extended upriver from the river mouth to beyond the station at km 58, where the water depth is less than 8 meters. The most severe dissolved oxygen (DO) condition occurred on the sloping bottom upriver of the deep basin instead of the deepest location. There were differences in DO distributions between times of spring and neap tides. The distribution during neap tide was highly stratified, while some degree of vertical mixing occurred during spring tide. However, the spring tide mixing in the Rappahannock River was not strong enough to eliminate the hypoxic condition in bottom water. A diagnostic study with a model of DO budget concluded that the hypoxic condition in the Rappahannock River is more locally driven than just an extension of the hypoxia in the mainstem of the Bay. The intrusion of low DO subpycnocline waters from the Chesapeake Bay occurred as episodic events during periods of strong south or southwest wind when the pycnocline was tilted.

### Plankton

VIMS/SMS continues to lead the scientific world in the use and development of state-of-the-art technology to enumerate and characterize the estuarine plankton community. These applications include silhouette *in situ* photography (and subsequent computer enhanced image analysis) for larger plankton forms such as zoo- and ichthyoplankton and color image analyzed fluorescence microscopy (CIAFM) for the study of smaller, microbial plankton populations.

CIAFM use in the lower Chesapeake Bay has provided new insights and questions about the dynamics of this important ecosystem. The presence of unexpectedly large numbers of coccoid cyanobacteria (bluegreen algae) of the genus *Synechococcus* has been detected during the summer months. These minute (ca. 1 micrometer diameter) photosynthetic organisms are known to make an important contribution to the primary production of certain coastal and oceanic systems, but little is

known about their role in temperate estuaries such as the Chesapeake Bay. Observations during the past few years indicate that these cyanobacteria reach a peak abundance throughout the lower Bay in July-August with concentrations as high as several million cells per ml, which is at least an order of magnitude greater abundance than observed in any other marine or estuarine system. A variety of efforts are ongoing to determine the factors responsible for the occurrence of this summer bloom. Particular interest is focused on the potential relationship of nutrient enrichment to the bloom.



Michael Sieracki is shown using CIAFM which he developed.

The CIAFM system is also being used to analyze populations of phytoplankton and microzooplankton from the Joint Global Flux Study (JGOFS), an international project to understand the processes that control carbon dioxide removal from the atmosphere by the ocean's surface waters. Plankton play a key role in the carbon uptake processes and the advanced technology of CIAFM enables us to have better plankton biomass and rate data in support of marine food web models and, ultimately, global atmosphere/ocean models.

In addition to putting CIAFM to use in the study of plankton processes, we are continuing to develop and improve the system's software and hardware. This ongoing development includes a collaborative project, funded by NSF, with a Virginia corporation to develop automated classification algorithms. The range of detection of particles is being extended to the sub-micrometer range by incorporating a cooled slow-scan CCD camera into the system.

The *in situ* photography system is a towed system which concentrates and photographs, on 35 mm film, live plankton. This system was developed for use in clear oceanic waters and our application to the local, turbid estuarine waters has been successful. Data retrieval from the film is presently manual, but image analysis will be developed. *In situ* photography, compared to traditional preservation and laboratory processing, is proving to be ineffective in estimating some species populations while



detecting other species which were not observed in preserved collections. To date the camera has provided reliable estimates of abundance of the following taxa: hydromedusae, polychaete larvae, a freshwater cladoceran, barnacle larvae, stomatopod larvae and eggs of striped bass and other fish species. The photographic technique is cost effective and is promising for producing the large volume of data necessary for reliable monitoring and modeling.

The plankton group, with funding from NSF, has been instrumental in providing research experience to eight minority undergraduate students in each of the summers of 1989 and 1990. There is widespread agreement that this kind of hands on research experience with scientists as mentors is both an effective teaching tool and an effective recruiting technique.

Efforts of the plankton group have also resulted in the establishment of a special collection of literature on the marine phylum Chaetognatha (arrowworms) in the VIMS Library. This collection was started with the donation, by Dr. George Grant, of a personal collection of reprints and books. Each entry is indexed by citation and key words for easy computer assisted retrieval. The collection is intended to provide a single and central repository of the literature for use by researchers.

### **Three-Dimensional Hydrodynamic Modeling**

The ability to predict water motion and the associated transport of dissolved and suspended materials in estuaries and the coastal ocean is a key element in the protection and management of marine resources. To provide VIMS and the Commonwealth of Virginia with this ability, an extensive program in three-dimensional estuarine and coastal ocean hydrodynamic modeling is being carried out in the Division of Physical Oceanography and Environmental Engineering under the direction of Dr. John M. Hamrick. The modeling program consists of a number of activities including: the development of a computer code or program which translates the mathematical equations governing the physics of fluid motion into a form which can be solved by a computer, the application of the computer code to simulate or model a particular physical situation, and the analysis and presentation of the simulated or predicted results using computer visualization tools.

Over the last two years, the three-dimensional computer code has been developed and applied to the James River. For this application, the river is divided into one quarter mile square horizontal cells stacked six high in the vertical, for a total of over 27,000 cells or volumes. The code provides the computer with instructions to calculate the movement of water and dissolved and suspended material

between the cells. A 12-hour tidal cycle can be simulated in slightly over one hour. To aid in the analysis of the model or simulation results, and to provide a means of presenting the results to resource managers, public officials and interested citizens, an extensive capability in computer graphics and visualization, including animation and video production, has been developed by the Physical Oceanography Division's computer scientists.

Future directions in the modeling program will include applications to the York River and lower Chesapeake Bay, the extension of the code to predict oil and hazardous material spills in real time, and the development of a companion water quality model.

### **Small Scale Physical Processes in Estuaries**

Acquisition of an Acoustic Doppler Current Profiler (ADCP) has significantly expanded our capability to map the complex flow patterns that characterize the estuarine and coastal environment. Through sophisticated acoustic signal processing, the ADCP can determine the current speed and direction at a series of levels through the water column based on sound pulses transmitted from just below the surface. By detecting and correcting for its own motion, the system is capable of operation from a vessel underway. VIMS researchers have developed a unique towing configuration for the ADCP that enables it to include currents very near the surface in the measured profile.

While these developments were in progress, we were fortunate to have the opportunity to host Professor John H. Simpson, on sabbatical leave from the University of Wales, Bangor. Professor Simpson's multi-disciplinary interests in estuarine processes meshed well with those of VIMS/SMS scientists in a variety of areas. The resulting resonance, along with his particular expertise in physical oceanography and his experience with ADCP systems, all contributed to a very active and productive period of research during his visit. Field experiments focused on investigations of a persistent tidal intrusion front in the James River near Newport News Point, the vertical and lateral structure of tidal flow in the lower York River, and processes controlling stratification in the upper York River.



*The Acoustic Doppler Current Profiler helps map complex flow patterns.*



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## EASTERN SHORE CAMPUS



*Bob Bisker prepares samples to do clam larvae counts in the Wachapreague hatchery.*

The main thrust of the research at this facility is a pilot-scale demonstration of hard clam *Mercenaria mercenaria* farming. The Wachapreague hatchery produces millions each of four to eight species of bivalves per year. Mr. Michael Castagna serves as scientist-in-charge for Wachapreague operations.

Testing nursery methods to increase survival during this vital stage is a primary focus for the Wachapreague hatchery. It was found that a com-

mercially available nitrifying bacteria could be used to reduce mortalities during the nursery stage, more than doubling the survival over the first three weeks in the system. Further tests are being run.

The annual clam course was given during both years of the biennium with participants from the east coast of the U.S. and from the Philippines. Visiting investigators to the Wachapreague lab included: Enrique Lara, Yaping Hu, Herb Hidu, T. Shane and two individuals from Thailand.

## OYSTER AQUACULTURE PROGRAM

Oyster production in Virginia has suffered a drastic decline during the last three decades. This decline is the result of two major oyster diseases, overfishing and water quality problems.

The primary goal of the program, under the direction of Mr. Michael Castagna, has been to spawn and grow selected stocks of oysters and then investigate methods for rearing these oysters to market size. To achieve this a state-of-the-art hatchery was established on the York River with Mr. Kenneth Kurkowski as its manager. Considerable effort was spent in solving the problems of growing oysters from spawned eggs through embryo and larval stages to metamorphosis in the face of chronic water quality problems that exist at this site. The hatchery has produced over 1 billion competent eyed larvae in the four years of the program. Variations of methodologies used in oyster culture elsewhere in the world have proven successful for setting and rearing of oysters in Virginia.

An important component of the program since its inception has been collaboration with the private sector. The relationship has been a mutualistic one in which the program has benefitted from the increased scope of its experiments and an infant industry has developed around the program.

In 1988 the Oyster Aquaculture Program completed its fourth year of an investigation of remote setting of oyster larvae. Over 235 million oyster larvae were distributed to nine industry collaborators. Techniques for setting these animals onto shells and holding them in a nursery

through an early growth phase in the intertidal before bottom planting for grow out were refined. While remote setting per se was successful, the problem of growing oysters in the face of the oyster pathogens *Perkinsus marinus* and *Haplosporidium nelsoni*, which have so decimated the wild fishery, remained.

From 1989 through 1990 the program has focused its attention on off-bottom marketable sizes before substantial losses to disease occur. Experiments at 11 different locations within Virginia waters that were initiated in 1989 under the supervision of Dr. Mark Luckenbach have not only shown this approach to be promising, but will yield about million harvestable oysters under two years of age.

A commercial scale off-bottom culture effort was initiated in Chesapeake Bay in 1990 with a goal of yielding at least million harvestable oysters before the diseases have a chance to take their toll.

Ongoing research is attempting to refine siting criteria and handling procedures with the goal of enhancing the commercial viability of off-bottom oyster culture. Presently, oyster aquaculture in Virginia appears poised to become a significant addition to the state fishery.



*Gustavo Calvo, Kathleen Greene and Mark Luckenbach work with seed oysters held in off-bottom racks.*

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## DEPARTMENT OF OCEAN AND COASTAL LAW

**M**r. N. Bartlett Theberge's research activities included a legislatively mandated pilot study of the ownership status of coastal lands in Accomack County, one of two counties comprising Virginia's Eastern Shore. The pilot study led to the identification of approximately 20,000 acres of previously unclaimed and untaxed state owned lands and provided members of the General Assembly with cost and benefit information better enabling them to determine a future course of action with regard to state policy and management of these lands. Because of the success of the pilot study, legislation was passed the following year

(1989) requesting an inventory of lands in Virginia's other eastern shore county, Northampton County, as well as a management and policy study. Prior to directed budget reduction this study identified approximately 10,000 acres of previously unclaimed and untaxed state owned lands in Northampton County. Additional preliminary work involving the management and policy aspects of the study is presently underway.

In the area of wetlands management, a comparative study of Virginia's and Maryland's approaches to wetlands management was completed.

## ESTUARINE RESEARCH RESERVE SYSTEM

**D**uring the 1988-1990 biennium, the Virginia Institute of Marine Science completed the nomination and pre-designation process for the proposed Chesapeake Bay National Estuarine Research Reserve System (NERRS) in Virginia. As a result of this effort under the direction of Ms. Carroll N. Curtis, Governor Baliles nominated four sites in the York River basin as the first components of the Chesapeake Bay NERRS in Virginia: 1) **Goodwin Islands** at the mouth of the York River and representing polyhaline salinity conditions (16-22 parts per thousand (ppt)); 2) **Catlett Islands** in the lower estuarine reaches of the York River and representing mesohaline (8-18 ppt) conditions; 3) **Taskinas Creek** in the transition zone of the York River and representing oligohaline (3-7 ppt); and 4) **Sweet Hall Marsh** in the Pamunkey River, a tributary to the York River, and representing tidal freshwater (0.5-5 ppt) conditions. The National Oceanic and Atmospheric Administration (NOAA), which administers the NERRS program, approved the four sites and awarded VIMS a grant to prepare a Draft Environmental Impact Statement and Draft Management Plan (DEIS/DMP) for the sites. The DEIS/DMP were completed and public hearings were held to receive public comment. Designation is expected in June of 1991. The NERRS sites will provide a network of protected sites for long-term research, monitoring, and education on natural and human processes occurring in the tributaries and

main stem of the Chesapeake Bay. The sites are natural areas which represent the variety of estuarine types found in Virginia. They are protected through conservation easements and management agreements with current landowners or through acquisition by donation or purchase. Sponsored research and monitoring programs are designed to enhance basic scientific understanding of estuarine systems and provide information that is helpful to resource management and decision making. Research reserves also enhance public understanding of and access to the Chesapeake Bay through educational programs, citizen monitoring, field trips, and various interpretive activities.

NERRS was created by the U.S. Congress pursuant to Section 315 of the Coastal Zone Management Act of 1972 (P.L. 92-583, 16 U.S.C. 1461). Recognizing the need to address threats to the nation's important and sensitive estuaries, Congress authorized grants to coastal states for up to 50 percent of the costs of acquiring, developing, and managing research reserves and for conducting research, monitoring, and education at designated sites. There are currently 18 NERRS programs in the United States and its territories. Four states (Virginia, Delaware, South Carolina, and New York) are completing the federal requirements for the designation of NERRS sites.



The Chesapeake Bay NERRS in Virginia offers a unique opportunity to enhance scientific understanding of coastal ecosystems and the impacts of natural and human-induced stresses on these environments. Technical information derived from directed

programs can provide a rational basis for intelligent management of coastal resources. Monitoring programs will be used to detect changes occurring within the estuaries and watersheds and to predict the consequences of anticipated population growth and land use changes. The research reserve program will also enhance local resource protection through the development and implementation of management agreements and conservation easements.

The proposed research reserves are natural areas which have received little disturbance by humans. The

Chesapeake Bay Program envisions the research reserves as being used for defining the functional relationships of coastal habitats and for monitoring the "health" status of these habitats in relation to

development within the Bay watershed. Because the reserves represent a cross-section of coastal environments in Virginia, they can also be used for research and monitoring which has much broader application, such as in developing coastal resource manage-

ment guidelines, in addressing regional resource protection needs, and in designing restoration or mitigation programs.

NERRS sites also aid in resource management through public education. The sites have been used for public and school field trips, teacher training sessions, and workshops for public officials. "Estuaries Day" and beach clean-ups have become a regular part of the reserve program's efforts to increase public awareness of the Chesapeake Bay estuary and the problems facing it. This

and other events and activities planned for the future will help bridge the gap between research, education, and decision making.



*Taskinas Creek in York River State Park.*



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## MARINE ADVISORY SERVICES



*Scientists James Kirkley, William DuPaul and graduate student Anne Schmitzer process sea scallops provided by local fishing vessels.*

Virginia's seafood and marine resources are important to the state and nation. The Commonwealth is one of the largest producers of seafood in the nation, ranking third in production and seventh in value landed. The ex-vessel value of marine products landed in Virginia exceeds \$80 million a year with the value of processed seafood exceeding \$146 million. The gross economic activity generated by the seafood industry exceeds \$250 million.

Marine Advisory Services' (MAS) role is to be directly responsive to the needs of industry and to

provide information which will heighten the public's awareness of the marine environment. VIMS MAS is coordinated with the MAS of the Sea Grant Program, a state/federal program administered through the National Oceanic and Atmospheric Administration. Since the 1960s, Sea Grant has assisted marine-related businesses through research, education and advisory services. This nationwide effort followed congressional concern about the decline of the U.S. fishing and marine-related industries.

### Offshore Research—Sea Scallops

Sea scallop research by MAS continues to provide information vital to this offshore industry, one of the most valuable fisheries in Virginia. Work in this area, conducted by Drs. William DuPaul and James Kirkley, involved examining spawning cycles, areal and seasonal differences in meat yields, and associated ramifications for management and enforcement. After evidence of a semi-annual spawning cycle in mid-Atlantic scallops was provided by MAS, the meat count regulation was modified on a seasonal basis; changes in meat weight relative to shell size—the basis of harvesting regulations—are significant during each spawning period.

Inquiries about the causative agent of yellowing associated with sea scallops held during stowage at sea resulted in research into this nagging and often costly problem to the sea scallop industry. Preliminary results offer not only an identification of the responsible microorganism, but also a low-cost detection device prior to the manifestation of the problem.

A major objective of the MAS sea scallop at-sea quality project, work performed by Mr. Robert Fisher and Dr. DuPaul, was to improve at-sea handling practices which would result in a better quality product at offloading. As a result of modifying vessel handling practices, changes made because of MAS findings and recommendations, a major U.S. buyer of sea scallops has substantially increased shipments from Virginia producers.

MAS recommendations pertaining to the proper application and optimum concentrations of sodium tripolyphosphate (STP), a processing aid, on sea scallops and the advantages of using salt in conjunction with STP have been widely adopted by scallop processors from North Carolina to New England. Scallop processors have been able to minimize and predict drip loss from frozen scallops with a substantial decrease in complaints from customers. Additional advantages have been noted by the lack of a "processing odor" and taste deterioration when STP and NaCl are used properly. Additional work will focus on projects to address freezing sea scallops at sea.

### Seafood Safety

The overriding concern for much of the seafood industry centers around the possibility of mandatory seafood inspection programs and the public perception of the safety and quality of seafood. Currently, an array of recommendations are being considered, all calling for a federal seafood inspection program based upon the Hazard Analysis Critical Control Point (HACCP) system. To assist industry in making the transition to an inspection program, MAS has actively been involved in developing a set of criteria for fishing vessels. Part of this effort includes developing education tools and programs for

vessels in the mid-Atlantic according to operational characteristics. Ultimately, the adoption of HACCP criteria by vessels could be a formidable marketing tool. Seafood quality assurance and safety is a national priority of substantial importance to Virginia and will continue to be a focus of MAS efforts.

### Specialty Markets

The development of specialized seafood product forms, or species with certain characteristics targeted to a specific market, can greatly increase the value of traditional or undervalued species. Also, increased profitability, better utilization and new market penetration are important to the survival of wild-caught fisheries.

MAS demonstrations and educational materials targeted toward full utilization of monkfish, harvested as a sea scallop by-catch, initiated the Virginia landings of monkfish livers for the commercial market. Proper techniques for cutting, packing and icing, and methods for facilitating buyer-producer contracts have resulted in a viable by-catch product suitable for export markets. These handling and stowage methods, developed by researchers Dr. DuPaul and Mr. Fisher for specialized products, significantly increase the value of the existing resource and provide additional income to vessels and crew.

MAS also worked with two scallop shell-stock shucking plants and several vessels in the development of the proper cutting and packaging of roe-on scallops. This product, new to the U.S. market, has a high export value, and demand for mid-Atlantic roe-on scallops during the winter months is increasing. A roe-on scallop has an increased market value over the traditional shucked meat and again offers a new export opportunity.

### Clam Relaying

The relaying of marginally polluted hard clams in containers has become a major industry innovation during the past two years. This is the result of work by MAS researchers Mr. Michael Oesterling and Dr. DuPaul, VIMS scientists, industry and



*Clam relaying operation.*

government.

A relay system involves taking clams from marginally polluted beds and placing them in areas free of contaminants. Clams, which are filter feeders, pump large volumes of water through their bodies. When placed in better water conditions, the clams are cleansed of impurities within a few weeks.

An initial demonstration project in 1986 resulted in modified regulatory measures to permit containerized relaying and concomitant industry adoption. In 1989, 10 of 12 hard clam relaying permits had converted to containerized systems, relaying over 35 million clams with reports of only minimal (less than five percent) losses. Traditional relaying techniques frequently resulted in losses exceeding 20 percent. In addition to instilling more consumer confidence in shellfish products, containerization provides for the better utilization of natural resources by permitting total recovery of the relayed shellfish; it offers the relay operator the potential for economic gain by taking shellfish from waters not classified for harvesting for direct human consumption (a low or no value animal) and in a short while have a marketable product.

#### **Soft Shell Crab Shedding**

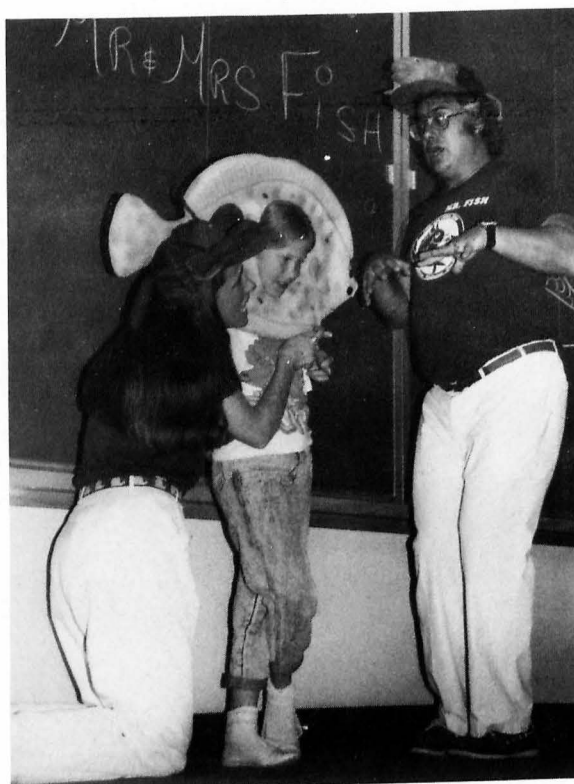
The soft shell crab industry of Virginia annually generates over \$1 million in dockside value. The techniques for producing soft crabs went unchanged for almost 100 years before new developments dramatically transformed the manner in which crabs were produced. Soft shell crab production in recirculating water systems, developed with the assistance of Mr. Oesterling, has permitted the expansion of production away from the waterfront.

Most recently, a demonstration project designed to test the feasibility of heating closed, recirculating shedding systems proved to be a major success. Within one year of the demonstration project and follow-up workshops, 12 closed systems were heated for the 1990 shedding season. The magnitude of the benefits attributed to heating far exceeded expectations; system bio-filters become conditioned prior to the first shedding run, heated systems were shedding crabs two to three weeks prior to unheated systems, and early season prices for soft crabs were realized by Virginia producers for the first time, an opportunity previously enjoyed only by producers from the more southern states. MAS performed research on this subject, conducted workshops and produced advisories for industry.

The export market for soft crabs, an area in which MAS has also provided assistance, continues to expand and is estimated to be in excess of \$5 million per year.

#### **Marine Education**

Since much of Virginia's economic well-being depends upon marine resources, it is apparent that



all of the public has a growing need to be aware of the marine environment and its resources, potential and problems. For many citizens, this means a need for marine education at non-technical levels, a role filled by Marine Education Coordinator Lee Lawrence and Education Specialist Sue Gammisch.

Recent publicity and tangible governmental commitment to the Chesapeake Bay cleanup have inspired the interest of the general public. To a great extent, the current political and popular emphasis on the Chesapeake Bay are providing a framework through which the region's marine educators coordinate and organize efforts. Events in recent years have carried MAS to an active position in both shaping and implementing Virginia's Chesapeake Bay education efforts.

Standard teacher education degree programs seldom include marine topics, and commonly used school textbooks and teaching materials typically contain little or no marine information. Teachers, however, sometimes are required to, or wish to teach marine topics, and routinely turn to MAS for information. In an effort to bridge the gap between the lack of marine information in textbooks, MAS and other state agencies produced *Virginia's State Parks . . . Your Backyard Classrooms*, a 200-page teachers' guide to estuarine parks for environmental education. The guide includes 40 detailed and illustrated lesson plans; maps and information about the parks; worksheets; correlations with Virginia's Standards of Learning; resources lists; and a glossary. An 8-minute promotional video tape and a

brochure to accompany the guide were also produced.

During the summer of 1989, 20 gifted and talented Soviet high school students spent two weeks working with the VIMS/NASA Governor's School. MAS coordinated the project, which exposed students to research projects in wetlands, fisheries, benthic ecology, oyster biology and resource management.

The Bay Team continues to be a major focus of effort of MAS's marine education efforts. The Bay Team is Virginia's only state-wide, school-based program for Chesapeake Bay education efforts. During the 1988-89 and 1989-90 school years, the Bay Team provided lessons for more than 40,000 students, K-12. The Bay Team was awarded the Virginia Wildlife Federation's "President's Award" for its educational activities.

*Coastal Growth: A Delicate Balance* was completed in July 1989. This program has been awarded the EPA's Center for Environmental Learning's 1990 award for "Best Educational Project." In addition to copies being disseminated to secondary and college-level educators and resource centers, the video was broadcast by PBS throughout much of Virginia.

#### **Seafood Seminars**

More and more people are becoming aware of Virginia seafood products through MAS's popular Seafood Education Seminars, coordinated by Ms. Sue Gammisch. These sessions combine the expertise of Tidewater chefs with Virginia wine specialists, and the seminars underscore the health benefits of seafood. Every series of seminars consists of six, seven or eight classes, and each class has a theme.

At each seminar a chef leads a cooking demonstration and the class is taught how to prepare a three or four course dinner using a Virginia seafood. Marine scientists from VIMS discuss the natural history of marine species as well as the harvesting techniques currently being used.

A Marketing Excellence Award was presented to MAS for outstanding work in the seafood seminars. The award was given by *Seafood Business*, a national trade magazine. More than 75 programs competed for awards in the five categories.

#### **Recreational Fishing**

The number of recreational saltwater fishermen in Virginia is large and continues to increase. With this growth, challenges develop for MAS, in terms of fishery management issues, conservation programs, vessel safety and urban/community waterfront development.

MAS projects, directed by Marine Recreation Specialist Jon Lucy, included developing a fishermen-based data base for assessing catch rates on Virginia's artificial reefs and documenting catch

trends in the large pelagic fishery. The later project is being used by the National Marine Fisheries Service to develop a new index of abundance for school-size bluefin tuna; additionally, the data is being incorporated by NMFS into assessment of the northeast pelagic fishery.

Conservation is being promoted by MAS through a number of avenues, including a Tag and Release Study. Associated with the study is an effort to develop an advisory program for the recreational pelagic fishery that will provide estimated lengths and weights of white and blue marlin from video footage before the fish are tagged and released.

Boat owners need practical safety preparedness information, especially hands-on or on-the-water demonstrations. MAS work focuses on cold water survival techniques for vessel operators and conducts seminars to promote safety at sea.

Demand for developing and revitalizing major urban waterfronts, as well as small community shorelines, continues to build. At the same time, working, commercial waterfront users—who historically utilized the urban waterfront—are facing significant pressure to fit into a more recreational-oriented waterfront community. MAS works to ease conflicts by facilitating a better information exchange between all waterfront users, and by the inclusion of all groups in waterfront activities.

#### **Communications**

The *Virginia Marine Resource Bulletin* (MRB), MAS's 21-page glossy magazine, is being read by more than 7,600 people and is garnering more and more attention. The intent behind the magazine is two-fold: to relay information about MAS, Sea Grant, and VIMS work, and to foster interest in the marine environment.

Of special note is the positive response to, and the special uses of the MRB. One issue, on wetlands, was used by the North Carolina Division of Parks and Recreation as an educational tool for its own personnel. The Environmental Protection Agency requested copies of the same issue to distribute on Capitol Hill, once again as an informational tool. Copies were requested for state and local officials involved in decision making about wetland use. The MRB was even used in a graduate class on wetlands.

While the MRB may be the most visible printed product of Communications, it is only part of the work conducted by writer and editor Susan Waters. Booklets, advisories and brochures are also part of MAS Communications, and they can be divided into two rough categories: publications which aid industry in decision making and implementing new technology and practices; and publications for the general public.



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# Appendixes

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# APPENDIX I

## PUBLICATIONS

July 1, 1988 thru June 30, 1990

### Journal and Book Contributions

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123. **Neilson**, Bruce, Gary F. **Anderson** and Martha **Rhodes**. 1990. Eutrophication of Lake Matoaka: assessment and projection.

## APPENDIX II

### FACULTY

- Henry **Aceto**, Jr., Acting Dean of Graduate Studies and Professor of Biology. B.S., State University of New York, Albany; M.S., University of California, Berkeley; Ph.D. University of Texas.
- Gary F. **Anderson**, Instructor in Marine Science. B.S., Southampton College of Long Island University; M.A., the College of William and Mary. Physical Oceanography and Environmental Engineering.
- Jay D. **Andrews**, Professor Emeritus of Marine Science. B.S., Kansas State College; M.A., Ph.D., University of Wisconsin. Marine Fisheries Science.
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- Steven G. **Branstetter**, B.S., Missouri Southern State College; M.S., University of South Alabama; Ph.D., Texas A&M University.
- Eric B. **Garnick**, B.S., Antioch College; M.A., Boston University; Ph.D. Cornell University.
- Mark W. **Luckenbach**, B.S., University of North Carolina; Ph.D., University of South Carolina.
- Michael A. **Unger**, B.S., Michigan State University; M.S., Ph.D., College of William and Mary.
- Wolfgang K. **Vogelbein**, B.S. Long Island University; M.S., California State University; Ph.D. Louisiana State University.

## ASSOCIATE FACULTY

- Gary L. **Anderson**, B.S., Gustavus Adolphus College. Espey, Houston and Associates.



- Carl Richard **Berquist**, Jr., B.E., M.S., Vanderbilt University; Ph.D., the College of William and Mary. Division of Mineral Resources, Department of Mines, Minerals and Energy.
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- Cynthia **Jones**, B.A., Boston University; M.S., Ph.D., University of Rhode Island. Applied Marine Research Laboratory, Old Dominion University.
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## APPENDIX III

### FINANCIAL, ADMINISTRATIVE AND FACILITIES MANAGEMENT

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Despite the downward turn in Virginia's economy during the latter part of fiscal year 1989-1990, the Institute experienced a 25 percent financial growth during the 1988-90 biennium. State-funded activities increased 22 percent even though the Institute suffered a two percent mandated general fund budget reduction of \$217,000 in February of 1988. Sponsored research grew 35 percent. Employment levels increased by 54 filled positions or 14 percent. Highlighted below are several significant accomplishments which occurred during the biennium.

- The Institute was able to modernize its scientific equipment in the amount of \$430,000 due to the state's higher education equipment trust fund. This fund was created in 1987 to supplement the yearly equipment purchases of higher education institutions in order to reestablish state-of-the-art status.
- The Institute, in conjunction with the College of William and Mary, began using an on-line accounting and budgetary system in July of 1987. Training has continued since the inception of the system to provide a better flow of management information and accounting data by the means of better management report writing software and more timely and accurate information feed. During the 1988-90 biennium, a human resources module was installed and is now operational for payroll purposes. In addition, the purchasing sub-module under the financial system has been implemented.
- The Institute continued its commitment to increasing funds available for research and education by expanding its search for external support. Active awards during the biennium totalled almost \$15 million, with expenditures over \$9.5 million and indirect cost recoveries in excess of \$1.78 million.
- The Institute received unqualified audit opinions both years of the biennium. In addition, it met the state's management standards which were approved by the Governor for institutions of higher education in Virginia beginning in fiscal year 1988-89. These standards include: 1) an unqualified audit opinion; 2) no major audit deficiencies; 3) qualified compliance with financial reporting standards; 4) attainment of accounts receivables standards; and 5) attainment of accounts payable standards.
- During the biennium, the Facilities Management Department continued its efforts to provide the best possible facilities in order for VIMS/SMS employees to effectively accomplish their assigned duties. Highlights of those efforts are listed below:
  - Completed planning of Scientific Storage Building to include two laboratories, a receiving/autopsy room, and library and storage space for the Institute's Marine Vertebrate Research Facility and Fisheries Collection.
  - Renovation of two wet laboratories - one in the Marine Culture Laboratory building, the other for the Experimental Mesocosm Laboratory.
  - Completion of renovation and expansion of Byrd Hall Wet Laboratory project.
  - Renovation of Hall House for the Institute's Ocean and Coastal Law Department.
  - Installation of Estuarine Research Reserve System in newly acquired Brown House.
  - Siting and installation of donated modular unit for Coastal Inventory Facility to include foundation, utilities connections and minor finishing.
  - Establishment of an underground network system for communications/computer cables.
  - Establishment of a Recycling Center as part of Utility Services Department.
  - Expansion and closure of Institute property lines with the acquisition of six parcels of privately owned property in accordance with the Institute's Master Site Plan.
  - Renovation of second floor of Maintenance Garage Building, and establishment of Customer Service Center to include under one roof offices for Buildings and Grounds, Property, Housekeeping, Purchasing, Pool Cars and Trucks and Central Stores. Renovation of Maintenance Shop Area and establishment of Customer Service Center Annex to include Housekeeping Operations Center and the Plumbing, Electrical and Paint Shops and Property Holding Area.

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## APPENDIX IIIa

### FINANCIAL ACTIVITY

July 1, 1988 - June 30, 1990  
(in thousands)

RESEARCH PROGRAM AREAS		STATE FUNDS	SPONSORED RESEARCH	TOTAL
I.	Investigate the fisheries of Virginia and factors affecting fluctuations in abundance.	\$ 2,992	\$ 2,900	\$ 5,892
II.	Investigate and define the distribution of benthic animals and communities and their interactions with the biological, physical and chemical environment.	267	464	731
III.	Develop an understanding of plankton processes in the Chesapeake Bay system and Virginia coastal waters.	556	499	1,055
IV.	Describe and evaluate the tidal fresh-water ecosystems of Virginia's major rivers.	159	119	278
V.	Investigate structure and function of mesohaline marshes and submerged aquatic vegetation.	606	405	1,011
VI.	Study diseases of marine and estuarine organisms.	529	69	598
VII.	Develop and perfect methods and techniques for economical culture of marine and estuarine organisms.	831	12	843
VIII.	Determine the fate and effect of toxic chemicals in the Chesapeake Bay system.	1,645	1,765	3,410
IX.	Study nutrient cycling processes and controls in riverine, estuarine and coastal marine environments.	254	212	466
X.	Evaluate factors leading to, and the consequences of, nutrient enrichment.	158	46	204
XI.	Understand the dynamics of benthic boundary layers and associated processes of sediment resuspension, transport, and animal-sediment interaction on coastal and estuarine environments.	284	15	299
XII.	Describe and understand the circulation of waters in the estuarine and coastal environment.	859	463	1,322

XIII. Develop a better understanding of shore-face, surf zone and beach processes.	\$ 162	\$ 313	\$ 475
XIV. Describe and explain the late Quaternary sedimentology, stratigraphy and geological evolution of the Chesapeake Bay and coastal waters.	213	37	250
XV. Conduct investigations related to the development, utilization, and management of resources of significance to the marine environment.	<u>678</u>	<u>481</u>	<u>1,159</u>
Total Research	<u>\$ 10,193</u>	<u>\$ 7,800</u>	<u>\$ 17,993</u>
<b>MONITORING PROGRAM AREAS</b>			
I. Fisheries	\$ 56	\$ -0-	\$ 56
II. Plankton	17	61	78
III. Bacteria (Lower York River)	-0-	1	1
IV. Parasites and Pathogens	-0-	-0-	-0-
V. Benthic Invertebrates	7	5	12
VI. Estuarine Plant Communities	83	78	161
VII. Coastal Erosion	57	326	383
VIII. Physical and Chemical	<u>53</u>	<u>154</u>	<u>207</u>
Total Monitoring	<u>\$ 273</u>	<u>\$ 625</u>	<u>\$ 898</u>
Advisory Services	\$ 1,158	\$ 1,125	\$ 2,283
Education	<u>\$ 1,191</u>	<u>\$ 2</u>	<u>\$ 1,193</u>
Total Research, Monitoring, Advisory, and Education	<u><u>\$12,815</u></u>	<u><u>\$ 9,552</u></u>	<u><u>\$22,367</u></u>
<b>Support</b>			
Service Centers (net)	2,002	-0-	2,002
Library	545	5	550
Research and Academic Administration	1,907	-0-	1,907
Financial Administration	3,450	-0-	3,450
Physical Plant	3,029	-0-	3,029
Other Institutional Activities	32	-0-	32
Parking Program	-0-	8	8
Total Support	<u>\$10,965</u>	<u>\$ 13</u>	<u>\$10,978</u>
Capital Projects	580	-0-	580
<b>GRAND TOTAL</b>	<u><u>\$24,360</u></u>	<u><u>\$ 9,565</u></u>	<u><u>\$33,925</u></u>



## APPENDIX IV

### VIMS ASSOCIATES

The VIMS Associates provides an avenue for private individuals and organizations interested in preserving the quality of the marine environment to support the work performed at the Virginia Institute of Marine Science. Through their gifts the members of the Associates play an active role in continuing the vitality of the Institute and advancing its service to the Commonwealth of Virginia and the nation.

The faculty, staff and students gratefully recognize the generous support received from the following individuals and organizations between July 1, 1988 and June 30, 1990.

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R. Kenneth Weeks Engineers  
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